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Symposium on Carcinoma of the Lung

MORPHOLOGIC ASPECTS OF CARCINOMA OF THE LUNG

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MANY recent contributions emphasize the importance of carcinoma of the lung as a clinical problem. From them it is evident that during the past two decades the number of patients with this condition has increased alarmingly, that the clinical methods of recognition have been improved, and that many laudable attempts have been made to alleviate it. The reason for the increased incidence is still unknown. It seems likely, however, that changed environmental conditions, newly acquired habits, and the increase in the number of persons reaching late middle life and old age have something to do both with the cause of the disease and with the increase in its incidence. With the ample opportunities available for the study of carcinoma of the lung at necropsy, more information can be gathered about the relative frequency, the race, sex, and age incidence, the sites of occurrence, the gross appearance, the probable cellular origin, the cellular structure, and the mode of spread of these growths. Such information is perhaps the safest guide to the early recognition and rational treatment of carcinoma of the lung, as it is of carcinomas arising elsewhere.

Relative Frequency.—Recent surveys of malignant neoplasms in the necropsy material of Charity Hospital of Louisiana at New Orleans by Ogden, Pearson, D'Aunoy, and Halpert[1-4] disclosed the following pertinent data: Among 7,433 necropsies on individuals over 1 year old, which were performed between Jan. 1, 1931, and June 30, 1939, there were 92 cases of carcinoma of the lung, 169 cases of carcinoma of the stomach, 50 cases of carcinoma of the pancreas, and 56 cases of carcinoma of the biliary system. In the Charity Hospital necropsy mate-

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rial, therefore, carcinoma of the lung was more than one-half as frequent as carcinoma of the stomach and almost as frequent as carcinoma of the pancreas and carcinoma of the biliary system together.

Race, Sex, and Age Incidence.—Three thousand one hundred and seventy of the 7,433 necropsies were performed upon white and 4,263 upon colored subjects, a proportion of 3:4. Carcinoma of the lung, however, occurred 53 times among the white and 39 times among the colored subjects. In the total necropsy material there were 4,801 males (2,183 white, 2,618 colored) and 2,632 females (987 white, 1,645 colored), a proportion of almost 2:1. Carcinoma of the lung, however, occurred 86 times among the males (48 white, 38 colored) and six times among the females (5 white, 1 colored). The youngest patient was 21 and the oldest 75 years of age. One died in the third, 4 in the fourth, 16 in the fifth, 39 in the sixth, 27 in the seventh, and 5 in the eighth decade of life. Seventy-seven per cent of the patients with carcinoma of the lung were thus in the sixth decade of life or older.

Sites.—The main growth was located in the right lung in 49 cases and in the left in 38. In the remaining 5 cases the site could not be determined. Carcinoma of the lung thus occurred somewhat more frequently on the right than on the left side. In 42 cases the primary growth was located in the right or the left bronchus, 10 in this group being located at or near the bifurcation of the trachea. Thirty-five growths were located in a branch of a bronchus. In almost one-half of the cases in this series, therefore, the growths were in a situation accessible to bronchoscopic visualization but in many instances, because of their location at or near the bifurcation of the trachea, they were inaccessible to operative removal.

Gross Appearance.—In the 92 cases which comprise this series the diameter of the mass which formed the primary growth varied from 2 to 15 cm. In the early stages, however, the growth may be represented by a nodule in the mucosa only a few millimeters in diameter; this nodule later may grow to a bulky mass 15 cm. or more in diameter and may replace almost an entire lobe of the lung. The bronchus or the branch in which the growth arises is usually somewhat off center of the contiguous tumor mass. The bronchial wall is eccentrically thickened and the mucosal surface is usually somewhat ulcerated about the area of maximum involvement. Narrowing of the lumen, with obstruction, is more frequently caused by infiltration than by projection of the growth into the lumen.

The gross appearance of the neoplasm depends less on the actual cellular structure of the growth and its stroma than on the size, the extent of involvement, and, in particular, the amount of softening, necrosis, hemorrhage, and secondary changes in the involved and adjacent pulmonic tissue. The gross appearance, therefore, yields no defi-

nite criteria by which the microscopic structure of the carcinoma can be predicted with any degree of certainty. The malignant character of the growth is usually evidenced by the excess of gray or yellow-white tissue of varying consistency, which is dotted with red and brown areas of discoloration and with opaque areas of necrosis or softening. The blotting out of the pulmonic tissue by the neoplasm, the borders of which are indefinite, and the thickening and ulceration of the tributary bronchus or its branch, usually with involvement of the pleura and of one or more of the lymph nodes in the hilus, complete the picture of carcinoma of the lung progressing to the advanced stage.

Cellular Origin.—The concept that the parent cell of all carcinomas of the lung is the reserve cell has been set forth elsewhere.[5] Some of the reserve cells, like the basal cells of the epidermis, are lined up along the tunica propria, and their oval or elongated nuclei form one or several rows. Their cytoplasm is scanty and their cell borders are scarcely discernible. The ciliated columnar cells and the goblet cells are ordinarily replenished from them. The reserve cells appear to be the only epithelial cells in the mucous membrane of the bronchial tree which are concerned with cell division and cell differentiation. They naturally possess, also, the qualities of their ancestor cells in that they may differentiate into any kind of epithelium which an endodermal cell is capable of producing. If we assume with Whitmore,[6] then, that the epithelial cells which replace other epithelial cells in a given area retain their embryonic potentialities, it is easy to see how in the course of forced and frequent cell division dominant characteristics may be supplanted by recessive ones, and how stratified squamous epithelium may be produced by the reserve cells. Such a concept offers a logical explanation for the variety in the cellular structure of carcinoma of the lung.

Cellular Structure.—On the basis of the individual and group characteristics of the neoplastic cells, carcinomas of the lung are classified as squamous-cell, columnar-cell, and reserve-cell carcinomas.

The growths are classified as squamous cell when the tumor cells are arranged more or less concentrically to form epithelial pearls, and the cells toward the centers of the cell nests disclose varying degrees of keratinization or are transformed into keratinized scales or debris (Figs. 1 and 2). The coincident presence of columnar cells which form acinar or tubular structures and of undifferentiated or reserve cells alone or in combination does not alter the grouping.

The growths are classified as columnar-cell carcinomas when the tumor cells are columnar or cuboidal and are arranged in acinar, tubular, or papillary structures (Figs. 3 and 4). The presence of additional masses of undifferentiated or reserve cells does not alter the grouping.

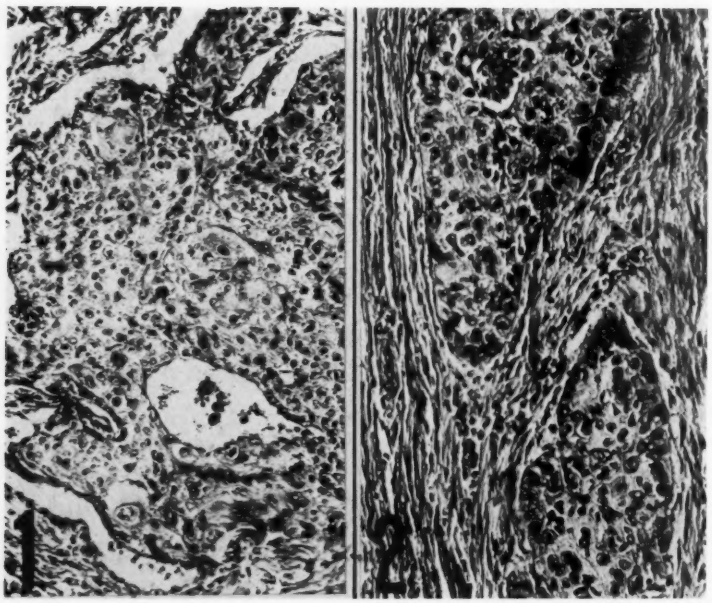

Fig. 1.—Squamous-cell carcinoma of the lung (59-year-old colored male). The cells toward the center of the cell nests disclose varying degrees of keratinization (Autopsy No. 38-114).

Fig. 2.—Squamous-cell carcinoma of the lung (56-year-old colored male). The cells toward the center of the cell nests disclose varying degrees of keratinization and a cellular debris (Autopsy No. 39-2).

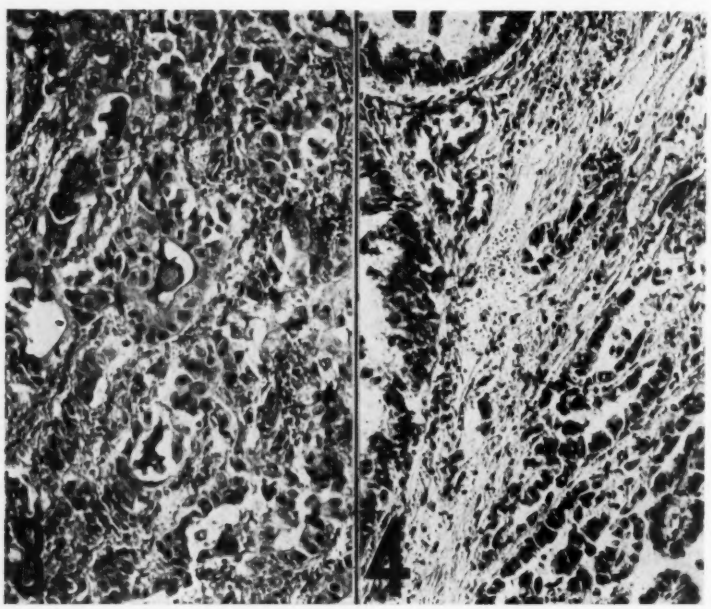

Fig. 3.—Columnar-cell carcinoma of the lung (49-year-old white male). The columnar or cuboidal cells in acinar or tubular arrangement simulate in a haphazard way normal epithelial structures of the air passages. The lumina of the acinar or tubular structures contain a pink or lavender staining secretion (Autopsy No. 36-346).

Fig. 4.—Columnar-cell carcinoma of the lung (54-year-old white female). The columnar cells are mounted on connective tissue stalks in a papillary arrangement (Autopsy No. 34-597).

The growths are classified as reserve-cell carcinomas when the tumor cells are of the same size; their nuclei are round, oval, or elongated and stain deeply; their cytoplasm is scanty, and their borders are scarcely discernible (Figs. 5 and 6). The cellular arrangement forms no particular pattern; in some growths the cells are arranged in whorls, in others there is a palisade arrangement of the peripheral cells.

Among the 92 cases of carcinoma of the lung which were analyzed, 49, over 50 per cent, were squamous cell; 17, approximately 20 per cent, were columnar cell; and 26, approximately 30 per cent, were reserve-cell carcinomas. In each of the three types there was considerable variation in the rapidity of growth, the amount and character of the stroma, the degree of inflammatory reaction in the stroma, and the extent of such secondary changes as hemorrhage and necrosis.

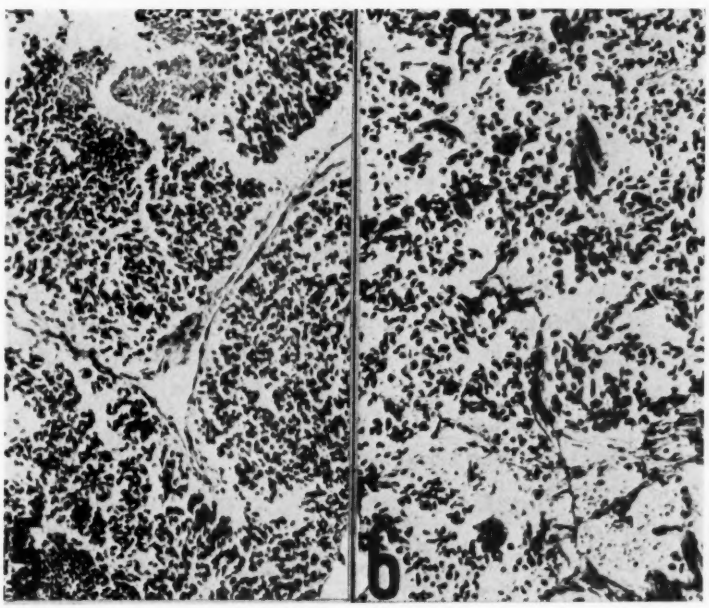

Fig. 5.—Reserve-cell carcinoma of the lung (59-year-old white male). The tumor cells are of about the same size; their nuclei are round, oval, or elongated, and stain deeply. The cytoplasm is scanty and the cell borders hardly discernible. Areas of necrosis are extensive in the centers of the cell nests (Autopsy No. 36-204).

Fig. 6.—Reserve-cell carcinoma of the lung (57-year-old white male). The tumor cells are of about the same size and are arranged in no particular pattern. The connective tissue stroma is scanty and delicate (Autopsy No. 31-99).

Manner of Spread.—The growth usually originates in the mucous membrane of a bronchus or one of its branches and extends into the deeper layers, involving the underlying pulmonic tissue. There is usually also a lateral extension in the mucous membrane which causes unevenness of the surface, eventually followed by ulceration. Local extension by contiguous growth and through the lymph and blood channels usually causes involvement first of the regional lymph nodes, then of the pleura, and later of more distant groups of lymph nodes, as well as metastases into distant organs.

Local extension with involvement of the regional lymph nodes occurred in 81 of the 92 cases. Extensive distant metastases occurred in 53 cases. Metastatic foci were encountered in the liver 28 times, in the suprarenal glands 13 times, in the kidneys 11 times, and in the pancreas and in the skeleton 9 times each.

COMMENT

It should be emphasized that the data just presented concern with few exceptions patients in whom carcinoma of the lung was the principal lesion and the immediate or contributory cause of death. In such cases the lesions are naturally far advanced, yet an analysis of the material offers much of interest.

Males between the ages of 41 and 60 years apparently comprise the majority of patients with carcinoma of the lung. The site of origin may be in either lung, and is usually in a bronchus or in one of its branches. In those instances in which the growth is easily seen through a bronchoscope, the operability is frequently poor because of the proximity of the growth to the bifurcation of the trachea. More amenable to surgical treatment, although less easily accessible to bronchoscopy, are those growths which arise in a branch of the bronchus.

Radiation therapy in carcinoma of the lung, as in carcinoma in other locations, depends upon the radiosensitivity of the neoplasm and its accessibility to adequate radiation. The cellular structure and the frequency with which the three types of carcinoma occur in the lung (over 50 per cent squamous-cell, about 20 per cent columnar-cell, and about 30 per cent reserve-cell) give the radiotherapist clues as to the result to be expected from radiation therapy.

The story remains to be told of a series of cases in which early recognition has led to prompt removal of the lung containing the growth.[7] A collection of such cases will soon be available for histologic analysis, and it will be of great interest to ascertain whether or not a particular type of carcinoma of the lung lends itself to early detection and to the application of successful therapeutic measures.

SUMMARY

Among 7,433 necropsies on individuals over 1 year old there were 92 carcinomas of the lung, more than one-half as many as carcinomas of the stomach and nearly as many as carcinomas of the pancreas and the biliary system together. Seventy-seven per cent of the patients with carcinoma of the lung were in the sixth decade of life or older. The proportion of whites to negroes in the total number of necropsies was approximately 3:4; whereas, carcinoma of the lung occurred in the proportion of about 1.4:1. The proportion of males and females in the total number of necropsies was almost 2:1; whereas, carcinoma of the lung occurred in the proportion of about 14:1. The growth occurred

somewhat more frequently on the right side than on the left. In almost one-half of the cases the primary growth was located in the right or the left bronchus. The gross appearance yielded no definite criteria by which the microscopic structure of the carcinomas could be predicted with any degree of certainty. Over 50 per cent of the growths in this series were squamous-cell, about 20 per cent columnar-cell, and about 30 per cent reserve-cell carcinomas.

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PRIMARY BRONCHIOGENIC CARCINOMA

A Clinical Study

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THOROUGH and exhaustive clinical studies of carcinoma of the lung have been undertaken with the expectancy that there would emerge definite clinical patterns, each pattern capable of recognition and representing a certain underlying pathologic process.

It is evident from the numerous reports thus far presented on this subject that a definite diagnosis of bronchiogenic cancer cannot be made without biopsy specimen and microscopic studies. However, we have learned a great deal from these studies, particularly a proper evaluation of important symptoms and signs as well as methods of differentiation from other pulmonary diseases.

In order to discuss this subject in detail, I will consider the following: age, sex, location of lesion, first symptoms, complications (such as bronchitis, emphysema, atelectasis, abscess, bronchiectasis, tuberculosis, silicosis, and infection), occupation, duration of disease, and methods of diagnosis in relation to bronchiogenic carcinoma, and analyze each separately.

Age.—The age incidence of carcinoma of the lung is approximately the same as for cancers of all other organs. The majority of cases occur between the fortieth and seventieth years, and rarely below the age of 20 years. Statistical studies have been made by Fried[1] at the Montefiore Hospital (New York); Graham, Singer, and Ballon[2] at Barnes Hospital (St. Louis); Maxwell and Nicholson[3] from Brompton Hospital (London); and Frissell and Knox[4] from St. Luke's Hospital (New York), as well as by others.

Table I

Age Incidence of Bronchiogenic Carcinoma

AGE YEARS	NO. OF CASES				
	MONTEFIORE HOSPITAL	BARNES HOSPITAL	BROMPTON HOSPITAL	ST. LUKE'S HOSPITAL	TOTAL
Under 30		1	8	4	13
30-40	11	6	20	5	42
40-50	27	13	41	6	87
50-60	52	23	30	17	122
60-70	45	10	5	14	74
70-80	15	3	3		21
80-90	2				2
Total	152	56	107	46	361

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These four statistical studies are similar in that the largest percentages fall in the fourth, fifth, and sixth decades. However, there are a sufficient number of cases in the younger-age group to warrant serious consideration of the presence of malignancy when the clinical signs and symptoms are suspicious.

Schwyter[5] reported an adenocarcinoma of the lung in a 16-month-old child. The patient became ill two months before her death, with loss of appetite and pallor. The left half of the thorax was entirely obscured by an effusion and there was extreme dyspnea. Death was due to diphtheria, and at autopsy the left lung was found to be invaded by a large mucoid tumor which extended diffusely through the parenchyma, leaving only a little atelectatic pulmonary tissue posteriorly.

Sex.—The question of sex in relation to carcinoma has also been studied by numerous authors. In my own series[2] of 56 cases, 42 were males, and 14 females. In Fried's[1] series of 152 cases, 123 were males and 29 females. Ferency and Matolcsy,[6] of Vienna, reported 282 cases, 204 of whom were males and 78 females. In the series reported by Frissell and Knox[4] of 46 cases, 36 were males and 10 females. A total of these statistics show 536 cases, of which 405 are males and 131 are females.

The predominance of carcinoma of the lung in males may be due to the fact that they are more susceptible to pulmonary irritation than are women and also that women develop carcinoma of the generative organs in a greater degree than men and die of this condition early in life. At present we are unable to state just why the proportion of male to female is so high.

Location of Tumor.—Fried[1] collected 1,639 cases from the literature; 1,034, or 63.7 per cent, occurred on the right side and 605, or 36.1 per cent, on the left. Bieberfeld[2] found 154 carcinomas in the right lung and 53 in the left, and Seyfarth[2] reported 258 right-sided cancers and only 49 left-sided. Fischer[7] reports in a series of 3,735 cases that 53 per cent occur on the right and 45 per cent on the left.

The location of the tumor in the right lung is more frequent than in the left, but, when one finds any lesion in the right or left lung, that fact does not lend much weight when considering the possibility of carcinoma because of the location.

Symptoms.—The early subjective symptoms of carcinoma of the lung vary so widely in different patients that it is difficult to decide when a patient's complaint may indicate the beginning of a malignant disease of the lung. Undoubtedly microscopic cells occur in the bronchus before symptoms appear and it is not until they involve structures which might produce pressure, pain, or hemoptysis that an individual will seek medical help. There have been attempts to classify the first symptoms in some series of cases.

Carlson and Ballon[8] analyzed the symptoms of 26 cases (autopsied) at the Barnes Hospital, St. Louis. They classified the symptoms of these cases into three groups: (1) local pulmonary symptoms, (2) general symptoms, and (3) symptoms suggestive of extension or metastasis. Table II shows the number of complaints according to frequency in these cases.

TABLE II*

SYMPTOMS UPON ADMISSION TO HOSPITAL (26 NECROPSY CASES)

	NO. OF CASES
I. *Local pulmonary symptoms (grouped according to frequency)*	
Cough	17
Chest pain or discomfort	11
Dyspnea	11
Sputum	10
Hemoptysis or "streaking"	6
"Chest colds"	2
(No chest symptoms 5)	
II. *General symptoms*	
Weight loss	9
Weakness	6
Anorexia	3
Night sweats	2
Thirst	1
Fatigue	1
III. *Symptoms suggestive of "extension," metastases, or unrelated disease*	
Nervous symptoms	8
Pain in back or extremities (not related to nerve pathways)	7
Urinary symptoms	3
Vomiting	2
Abdominal pain	2
Abdominal enlargement	1
Engorgement of veins	1
Precordial distress	1
Dysphagia	1

*Patients observed at the medical and surgical chest service, Barnes Hospital, St. Louis.

The cough is usually dry, harassing, and occasionally accompanied by blood-streaked sputum, and rarely frank hemoptysis. Chest pains are most significant and seem to be, especially in the early cases, much more severe than the physical signs would warrant; but in the absence of definite pleurisy and in the right age groups one must consider pain as an important symptom of the disease under discussion.

Dyspnea, which may become the most distressing symptom of all, does not occur early unless sudden atelectasis has taken place. In the slow contraction of the lung, dyspnea does not occur so readily, even when an entire lung is involved.

Weight loss does not occur early in the disease. The reason for this may be that this symptom develops when there is secondary involvement of other organs. Cachexia does not manifest itself until very late in the disease. Night sweats, fever, Horner's syndrome and clubbing of nails are also late symptoms.

The signs of metastasis are too varied for classification, but, when patients have signs of involvement of the lung and develop signs of metastasis to other organs, it must be considered as part of the same process.

The blood picture is not significant.

Because of recent therapeutic advance, particularly surgical approach, carcinoma of the lung can no longer be considered a hopeless condition. Consequently the clinical discovery of early cases becomes imperative.

Duration.—The duration of the illness, before the patient is aware of any involvement of his lung, varies from a few days to as long as twenty years. Some patients are more observing than others and, strangely enough, a rather large percentage of patients do not come until late in the disease and not then unless there is hemoptysis or excruciating thoracic pain. A careful history, however, of patients who might be suspected of having the disease will reveal conditions to the patient himself which may be significant in the true interpretation of the cause of the symptoms. Most of the patients, however, manifest the important symptoms which precede their death from one to fifteen months.

Occupation.—The occupation of patients who have carcinoma becomes important, particularly when carcinoma apparently follows some traumatic injury; especially for those persons who work where there is a hazard of trauma, particularly in coal mines, in an atmosphere of silica dust, or where inhalation of tar fumes is likely. In the well-known mining district of Schneeberg many cases of carcinoma have developed in the workers. There many investigators attribute the carcinoma to the inhalation of arsenic and cobalt, while others feel that it may be due to the inhalation of silica dust.

Lynch and Smith[9] report a case of carcinoma of the lung due to asbestosilicosis. This man was 57 years of age when he was first examined. His chief complaints were pain in the right side of the stomach and right side of the back and shoulder and shortness of breath. He had been exposed to dusty atmosphere when 16 years of age, working as a weaver in a cotton mill. Twenty years later he began to work as a weaver in an asbestos factory, a position he held up to the time of his entry into the dispensary in 1934. A diagnosis of silicosis and asbestosis was made and at autopsy an associated carcinoma was found in the lower lobe of the left lung. These authors feel that the chronic bronchial irritation was compatible with the current etiology of the carcinoma. In other words, they believe that the irritation of the bronchi may be a hazard of the type of work done in the development of carcinoma. However, it is so rare that one finds carcinoma associated with either silicosis or asbestosis that one may assume that the disease occurs in a patient who has other pulmonary involvement.

In a case I saw at the Barnes Hospital, St. Louis, a miner was struck by a small truck which pinioned him against the wall of the mine. He

developed bleeding from the lung which lasted for over a year. He died later and at the post-mortem examination a carcinoma was found in the lung in addition to the silicosis.

Experimental production of carcinoma by the exposure of mice to coal-tar fumes and also to exhaust from automobiles and by the painting of mice with tar apparently has no correlation to the development of carcinoma of the lung in man.

There are a great many workers in all occupations who develop carcinoma, though they are in no known way exposed to occupational hazards. This leaves the problem of the relationship of carcinoma to occupation still a question for study.

Types of Carcinoma of the Lung.—It is accepted by nearly all workers that carcinoma of the lung arises from the bronchial mucosa and not from the alveolar epithelium. Fried[1] has shown conclusively and it has been proved by others that the alveoli do not contain fixed cells which can produce carcinoma. He states:

"Carcinoma originating primarily in the lungs is bronchiogenic.

"There is evidence that when the disease is found in the lungs it results from a pathologic (excessive) regeneration following chronic inflammation of the bronchial tree.

"Of the three varieties of cells lining the bronchial mucosa, that is, the ciliated columnar epithelium, the goblet cells and the 'basal' cells, only the last are concerned in the process of regeneration of the bronchial mucous membrane. It is assumed, therefore, that these cells likewise serve as a sole matrix for primary bronchiogenic tumors.

"Similarly, primary squamous cell epitheliomas and basal cell epitheliomas of the lungs do not result from metaplasia of the pre-existing ciliated columnar epithelium, but originate through protoplasia (indirect metaplasia) of the undifferentiated basal cell of the bronchial mucous membrane."

Grossly, the types of carcinoma, as shown by the roentgen-ray film, have been classified by Lenk[10] as follows: (a) pure intrabronchial tumors, (b) carcinomatous pneumonia, (c) hilus carcinomas, (d) carcinoma involving a lobe, (e) the so-called lymphangitis carcinomatosa, and (f) interlobar carcinomatous nodules.

It must be appreciated that a roentgen-ray picture is due to not only the tumor mass but also the effects upon the bronchial tree; that is, atelectasis, bronchiectasis, or pneumonia. The roentgen-ray appearance may be due to metastases, a pleural effusion, pleural thickening, abscess of the lung, gangrene, or obstructive emphysema. There may be much fibrosis, pleural thickening and distortion of the mediastinum so that the picture is one of the unilateral opacity of the type which suggests a chronic fibroid tuberculosis.

In view of such different structures, therefore, the variations of symptoms and physical signs accompanying such changes must be expected.

Complications of Bronchiogenic Carcinoma.—Among the most important complications are: atelectasis of the lobe or lobes or even the entire lung, abscess, bronchiectasis, empyema, emphysema, bronchitis, and spontaneous pneumothorax.

Atelectasis is a condition which is produced by the presence of an intrabronchial mass which may block a main bronchus or one of the smaller bronchi, depending on where the tumor originates. The usual signs of massive atelectasis may be found sometime in the early papillomatous type so that one must not consider a complete density in a roentgen-ray film as evidence that the carcinoma itself is as extensive as the shadow would indicate. It is well known that, when bronchi are obstructed and atelectasis develops, infection of the pulmonary tree distal to the obstruction is frequently the site of abscess formation produced by anaerobic bacilli. Secondary to these abscesses it is not uncommon for bronchiectasis to develop. This triad of complications is most frequently met with in the majority of carcinoma of the lung, but it requires considerable diagnostic ability to be able to unravel the complications from the disease itself. Fortunately, with our present means, which will be discussed later, this so-called mystery of the shadows can be solved.

Accompanying diseases, such as tuberculosis, silicosis, and emphysema, do not seem to be complications as much as separate diseases in the same patient. A rather important complication is the development of fluid in the chest as a secondary manifestation of irritation. The original pulmonary involvement may be the lymphangitis carcinomatosis and this condition is rarely diagnosed except when there are metastatic lymph nodes available for biopsy or at a post-mortem examination, and then only when microscopic sections of the lung are studied.

Diagnosis.—The clinical diagnosis of carcinoma of the lung must be confirmed by many tests, but the only positive one is the finding of carcinoma cells in the lung tissue. The correct diagnosis in the past five years of this condition has risen from approximately 20 per cent to between 75 and 90 per cent of cases. This marked advance in more correct diagnosis has followed the more careful and exhaustive studies developed in the chest centers.

Physical Signs.—The signs elicited in a suspected case of carcinoma of the lung depend on the size, shape, and location of the tumor. In the miliary type no definite signs are noted, but, when the mass is large, dullness, bronchovesicular breath sounds, and increased whisper sounds are present. Râles may or may not be heard. Areas of emphysema may so surround the smaller masses that the signs of a mass are not elicited. In a patient who was under my care, the signs of obstructive emphysema were the only significant change from the normal. In this patient, his advanced age and the history of wheezing, cachexia, and frequent hemoptysis suggested carcinoma. By bronchoscopic examination one

could see the mass partially obstructing the lower right branchus. Air was able to enter the lobe but could not be forced out on expiration. A microscopic section of a biopsy specimen showed this mass to be a squamous-cell carcinoma.

The physical signs by themselves rarely are of diagnostic value without the other evidences of tumor.

Direct vision, by means of bronchoscopy, enables one to obtain exact information as to what is present in the larger bronchi. Today in all large medical centers well-trained bronchoscopists are available so that mistaken diagnosis by omission of bronchoscopy should not be excused. Removal of bits of tissue can be easily done and microscopic examination of them makes definite diagnosis possible. When the tumor is in the smaller bronchi, the bronchoscopic examination fails. If fluid is present in the pleural cavity, this can be aspirated and air injected. It is now possible to introduce a cannula into the pleural space under local anesthesia. A thoracoscope can be inserted into the cannula and a good view of the entire chest cavity can be obtained. At the same time it is also possible to take biopsy specimens of the pleura or lung tissue.

I have designed a thoracoscope[11] which has a universal adapter placed on the proximal end of a small oval-shaped cannula. Two openings in this adapter permit the introduction into the chest cavity of a small thoracoscope of the foreoblique type and operative instruments, such as galvanocautery, high-frequency electrode, long hypodermic needle, biopsy forceps, or catheter. The use of any one of the instruments permits direct vision. If the operator wishes to use the two-cannula method, another puncture is made with a second flat trochar and cannula, and the foreoblique lens is put in one instrument and the various operative instruments are introduced through the second opening. It is obvious then that this universal thoracoscope combines the value of both types of operation and permits the use of either method. Fig. 1 shows how the instrument is assembled.

The pleural fluid can be studied by the Mandelbaum method, which consists of centrifugalizing the fluid and then fixing the sediment as if it were tissue. Microscopic studies are then made. Finally, biopsy specimens may be taken by puncture with a large needle plunged into the mass, or even thoracotomy is indicated at times. Occasionally, even then, the pathologist may report atelectatic lung and fibrous tissue.

Roentgen Ray.—The use of the fluoroscope has been of particular value in our studies. One must spend considerable time in the darkroom before beginning to see the picture on the screen. The faint shadow becomes distinct when the eyes are accommodated and the normal is early distinguished from the abnormal. By fluoroscopy one can visualize patients from many angles and it is not infrequent that a homogeneous shadow in the film "dissolves" in such a way that one can note brilliant lung tissue behind or in front of the mass producing the shadows. The

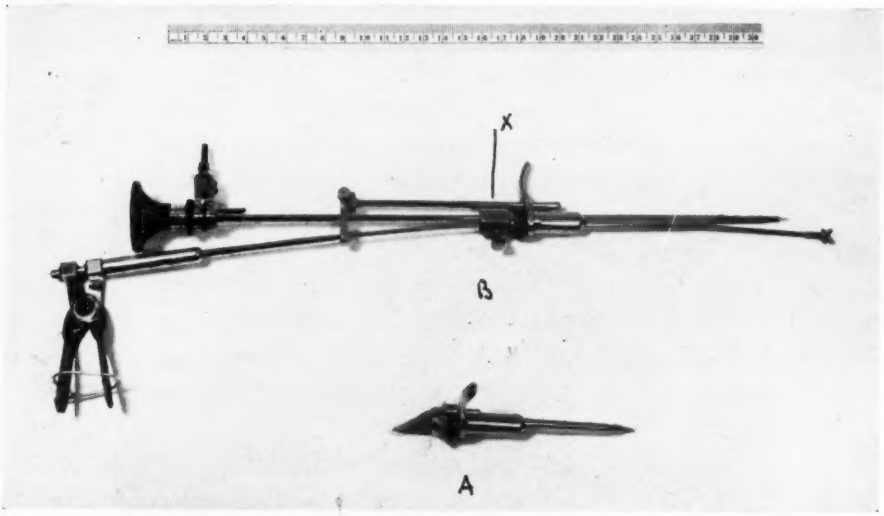

Fig. 1.—Photograph of Singer's universal thoracoscope assembled (made by Phillips-Drucker, St. Louis, Mo.). *A* shows small oval trochar and cannula; *B* shows the assembled instrument; *X* is the universal adapter through which the thoracoscope and operative instruments can be inserted.

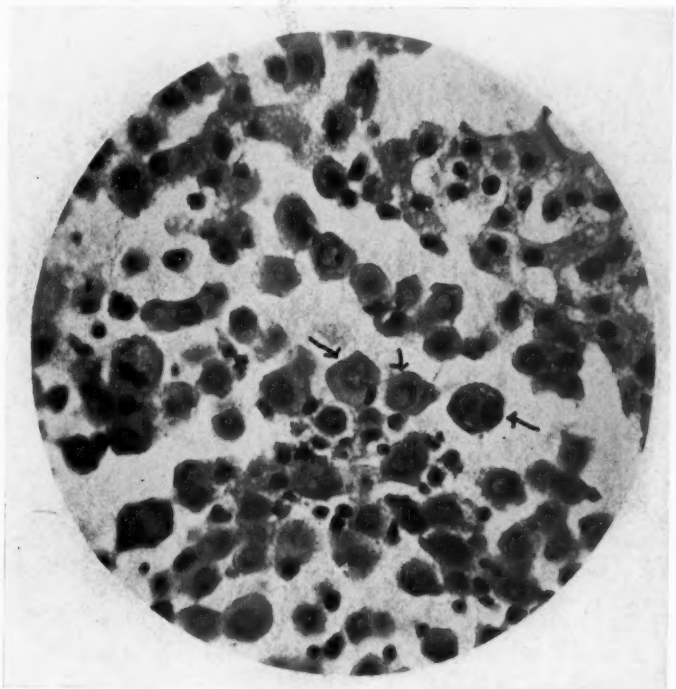

Fig. 2.—Specimen of chest fluid, April 25, 1939. Arrows point to tumor cells. Microscopic examination of paraffin section of centrifuged sediment of 30 c.c. of straw-colored fluid shows a large number of cellular elements; practically no red blood cells are seen. Groups of leucocytes are scattered along larger numbers of tumor cells. These cells vary considerably in shape and size; frequently they are polyhedral to oval; cell borders are distinct or, at times, fused. Cytoplasm is pale and coarsely granular; nuclei are large with, in many instances, large nucleoli. Some of the nuclei have vacuolization probably due to glycogen, but mostly they are light blue; some are hyperchromatic. An occasional bizarre mitotic figure is seen. Some multinucleated cells are present. *Diagnosis:* Carcinomatous extension or metastasis to pleura. (×500.)

combination of the physical signs, fluoroscopic examination, and roentgen films affords the factors upon which judgment can be based as to the character of the shadow.

When fluid produces the shadow, it is impossible to visualize the lung; but, when the fluid is aspirated and air is introduced (diagnostic pneumothorax), then roentgen ray becomes of greater value.

It is not unusual to see shadows in the lung which cannot be diagnosed as tumor, but careful study of the roentgen-ray appearance of ribs may show areas of rarefactions and even of spontaneous fractures. Thus, as these may be interpreted as evidence of metastasis in the bones, the shadow in the lung may also be so interpreted.

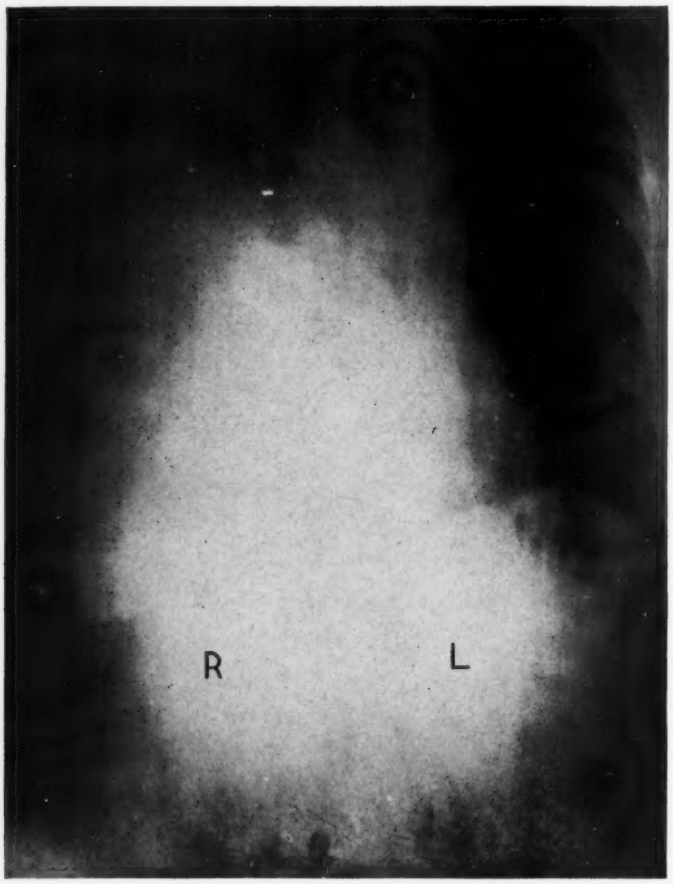

Fig. 3.*—Roentgen film of patient; upright position shows unilateral density on the right chest, except above the second rib. No displacement of mediastinum to the right.

Bronchography, by the use of iodized oil, has added exactness to our diagnostic methods. The closed bronchus and deformed distribution of the bronchial tree are easily recognizable.

*Figs. 3-6 show how one can, by diagnostic pneumothorax, separate the various components which produced the homogeneous shadow in the right chest. Biopsy by thoracotomy proved this mass to be a bronchiogenic carcinoma.

The newer methods of taking films by planography or tomography are also of great value in the localization of masses and cavitation.

The details of roentgen-ray studies will be discussed in full by others in this symposium.

CASE HISTORIES

CASE 1.—H. K., white, male, clothes cutter, aged 52 years. Entered Cedars of Lebanon Hospital on April 24, 1939.

His previous history shows that at the age of 32 years, during an attack of a so-called chest cold, he was told by his physician that he had a leaking heart. He did not recall any rheumatic fever and was asymptomatic until six years ago, when he first noticed dyspnea on exertion. Three years later he was forced to sleep

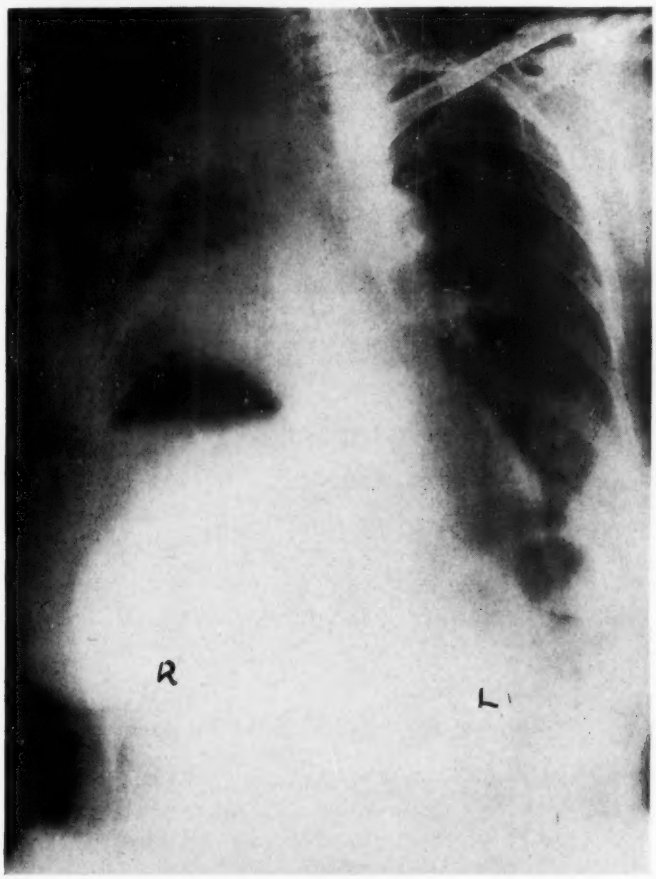

Fig. 4.—Roentgen film of patient, upright position after 500 c.c. of fluid was removed and 200 c.c. of air injected. Note the density between the areated lung above and the air pocket below. Mediastinum still not shifted.

in a chair because of "asthma." He has had occasional hemoptyses of brief duration in past eight years, and a few attacks of angina pectoris for the past year. He worked until three weeks before he entered the hospital, despite marked ankle edema, dyspnea, and orthopnea.

He entered another hospital at that time and was treated for cardiac decompensation by digitalis, rest, and the aspiration of two quarts of clear fluid from the chest. He did not improve, however. He had pains in the right chest and stated he lost ten pounds in the last year.

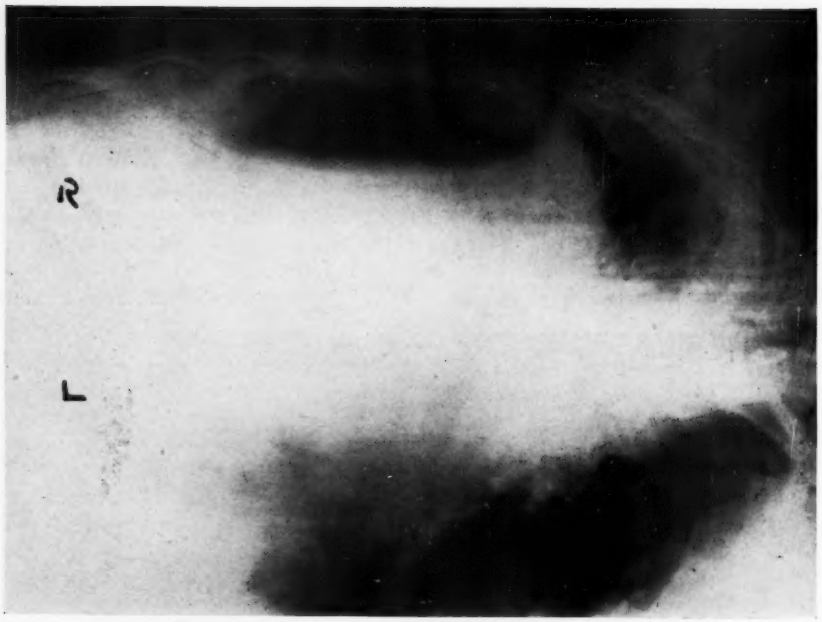

Fig. 5.—Roentgen film of patient, right horizontal lateral position. Air pocket now along the axillary area and shows no abnormal condition other than hazy right diaphragm. The pocket is limited by mass and adhesions at the second anterior rib.

Fig. 6.—Roentgen film of patient, left horizontal lateral position. Air pocket has shifted toward the mediastinum and limited there. One notes a density with concavity downward.

Physical examination showed an orthopneic, dyspneic, cyanotic, cachectic male. He showed signs of a large amount of fluid and air in the right chest with marked shift of mediastinum to the left. Heart sounds were faint and he had a systolic murmur at the apex. He showed ankle edema. His circulation time was as follows: venous pressure, 26.4 cm.; arm to tongue time, 27 seconds; arm to lung time, 11 seconds; and lung to tongue time, 16 seconds. These showed signs of decompensation. Three thousand cubic centimeters of bloody fluid was aspirated from the right chest and centrifugalized and the sediment embedded in paraffin. On three occasions this was done and only the first specimen showed some carcinoma cells.

X-ray examination of the chest showed a partial collapse of the middle and lower lobes on the right side. The upper lobe was only slightly collapsed, probably held by pleural adhesions. The density of the atelectatic middle and lower lobes prevented the visualization of an infiltration in the lung tissue.

Thoracoscopy was done on May 20, 1939, in the right chest. There was a small amount of bloody fluid in the costophrenic sulcus. The lung was visualized. The lower part of right lung, which was hard and almost immovable, was adherent superiorly. Its underlying color was densely white and there seemed to be thickening and infiltration of the parietal pleura. Biopsy specimen was removed from the parietal pleura and sent to the laboratory for examination. Microscopic section showed old fibrin mixed with large cells which varied some in size and shape. Numerous hyperchromatic nuclei were present. No mitotic figures were seen. *Diagnosis:* metastatic carcinoma to pleura.

The patient died two days later. A post-mortem examination showed that the right lung was involved by miliary bronchiogenic carcinoma.

Comments.—The history of this case was not suggestive of carcinoma by any of the clinical diagnostic standards that we have. The x-ray examination was not suggestive of a malignancy. However, the clinical inferences as to the possibility of carcinoma were his age, marked loss of weight, hemoptysis, and bloody fluid in the right chest. While he had an associated cardiac decompensation which overshadowed the symptoms of malignancy, careful analysis of the various conditions present lent some weight to the possibility of malignancy and therefore a biopsy through the thoracoscope was done and a positive diagnosis of malignancy was thus obtained.

CASE 2.—M. K., white, male, aged 62 years, entered Cedars of Lebanon Hospital on Feb. 3, 1937.

He had a past history of pneumonia at the age of 28 years. His chief complaints at admission were pain in the right chest, hemoptysis, loss of weight, weakness, and anorexia.

Physical Signs.—In the lungs there was a generalized impairment of resonance over the right lung field by a mass particularly limited to the upper and middle lobe. Occasional moist râles were heard over this area. Breath sounds diminished over this area. Left lung showed no abnormal signs.

X-ray examination of the chest on Feb. 4, 1937, showed a radiopacity over the entire right upper lobe. The trachea and mediastinal contents were not displaced. A radiopaque patch, the size of a walnut, was present at the right hilus, probably due to extension of the tumor mass in the right upper lobe. The right costophrenic angle was slightly obscured, probably by fluid. The pleura was somewhat thickened.

The patient was bronchoscoped on Feb. 8, 1937. The left main stem bronchus was explored and found to be normal in appearance and unobstructed. The orifices

were similarly normal. An excellent view was obtained of the right upper lobe bronchus. This region presented no inflammatory or neoplastic changes. The orifice was shrunk with neosynephrine and a sponge inserted into the branch to the right upper lobe. There came away on the sponge a large gelatinous, thick, tenacious mucous plug which may well have obstructed this bronchus. No further positive changes were present.

On Feb. 12 thoracentesis was done, with the puncture site between the third and fourth ribs in the posterior-right side. No fluid was obtained.

Punch biopsy was done into the mass on Feb. 25. A few shreds of tissue were obtained, the microscopic report of which was negative for carcinoma. It was then decided that an open thoracotomy should be done to see if the density was due to an abscess. A portion of the third rib was removed posteriorly and biopsy taken of the pleura and attached lung. This was examined microscopically and the section showed mostly fibrous tissue in which there were areas of round-cell infiltration. This can be interpreted as thickened pleura. There was one small piece of lung tissue in which there was considerable atelectasis and the few remaining alveoli were filled with phagocytic cells and blood pigment. No evidence of neoplasm was seen in any of the sections at hand. The patient became weaker and finally died at his home on Jan. 20, 1938. An autopsy revealed the following: The pleural surface of the right lung showed dense, fibrous thickening. The lung was nodular and suberepitant in consistency. The main bronchus to the right upper lobe just distal to its bifurcation was almost entirely occluded, except for a minute lumen of about 1 mm., by a firm mass of cellular, grayish-white tissue which appeared to rise from the mucosa and which infiltrated into the adjacent lung substance for a distance of about 3 cm. The branches of this bronchus distal to the point of obstruction were dilated and showed a necrotic reddish-purple surface.

Microscopic examination.—Sections from the main mass of the tumor described grossly showed very extensive necrosis of the tumor about the periphery. There were frequent clusters of viable tumor cells. These were arranged in irregular clusters and strands and solid, cellular cords. In many places large areas of tumor tissue were necrotic, except at the very periphery where there were viable tumor cells. Generally the tumor cells were small and undifferentiated. They formed frequent epithelial pearls in places, although it was not possible to demonstrate intracellular bridges in these areas and it was questionable whether these were active epithelial pearls or areas of beginning necrosis. Their appearance and the fact that the tumor remained so well confined to the lung suggested that these were true squamous epithelial pearls. Adjacent and supporting connective tissue showed very dense hyaline fibrosis.

Comments.—The clinical history, symptoms, and signs all pointed to carcinoma: loss of weight, edema, hemoptysis, cough, severe pain, and x-ray. Yet, at no time, in spite of biopsies being made, even with rib resection, was carcinoma positively diagnosed. This case is described to show how, with all means at our command, the final diagnosis at times is made only at autopsy, although clinical signs may be so definite that the patient can be treated as having carcinoma of the lung.

SUMMARY AND CONCLUSIONS

The clinical picture of carcinoma of the lung is still so varied that no definite pattern has been discovered to fit the many types of pathologic conditions present. However, with close observation of the patients and

taking into consideration the many factors discussed, such as age, location, complications, and sex, and also with the aid of the many diagnostic methods, very few cases of carcinoma of the lung are now overlooked. In view of the fact that surgical approach in early cases of carcinoma of the lung has been proved successful in many instances and with the increased proficiency of the surgeons in this field, it behooves all medical men to search out these early cases if we are to benefit our patients. From the analysis of the various circumstances surrounding this subject which has been discussed, certain highlights are present.

These are that, given a patient in the ages between 40 and 70 years, with symptoms of pulmonary disease with special reference to cough, pain in the thorax, and hemoptysis, the examiner should stress his studies in the search for malignancy of the lung as a probable etiologic condition of the patient's complaints. The advances in our diagnostic ability have been for the most part improvements in roentgen-ray technique, bronchography, bronchoscopy, the study of pleural fluids for malignancy cells, thoracoscopic biopsy, and also punch biopsy.

In vague pulmonary diseases, if all the signs remain indefinite for a diagnosis of carcinoma, one should search for evidences of metastasis in the lymph glands of the neck and axillae and evidences of metastasis should be searched for in the brain, ribs, kidneys, and rarely the skin. In cases that have been operated upon for carcinoma elsewhere, even as long as twenty years before, studies of the chest should be made for metastatic involvement of the lungs. Sooner or later a large number of patients so operated upon develop malignant lesions in the lung.

Finally, the clinical picture of bronchiogenic carcinoma is frequently masked by the complications.

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BODY-SECTION RADIOGRAPHY IN MALIGNANCY OF THE LOWER RESPIRATORY TRACT

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CANCER of the lung is of more frequent occurrence than is generally supposed. It comprises from 5 to 10 per cent of all cancers and is about equal in incidence to cancer of the rectum. In fifteen years in the Chest Service of the Washington University Medical School there have been 400 cases of bronchiogenic carcinoma.

An unfortunate feature of pulmonary cancer is the fact that in the neighborhood of 85 per cent of the cases are advanced and, from the therapeutic standpoint, practically hopeless, because of distant metastases, such as to the supraclavicular lymph nodes, brain, pleural implantations, mediastinal involvement indicated by paralysis of the recurrent laryngeal, or phrenic nerves. Under these conditions radiation treatment offers little except palliation, and surgery, nothing.

With the rapid development of thoracic surgery of the past few years, surgical excision by lobectomy or pneumonectomy can be carried out for pulmonary cancer with brilliant results, providing a sufficiently early diagnosis has been made. As a choice between radiation treatment of early cancer of the lung and its surgical excision, there can be but one, and that is excision. Taking all types of cases of the surgical attack on pulmonary carcinoma, the mortality rate is in the vicinity of 30 per cent of the cases operated upon, and results are steadily and constantly improving. In ten successive examples of pneumonectomy and lobectomy for pulmonary carcinoma there was only one operative death. Operative technique has improved to the point where the hospitalization and postoperative care are being constantly bettered, and the patient is being restored to his normal occupation in a shorter time than previously. It has been stated that approximately 65 per cent of all cases of intralumenal, bronchiogenic carcinoma can be diagnosed and located by symptoms, physical signs, bronchography, and bronchoscopy. This figure seems too high. It may be true for the lower half of the lung, but there could scarcely be such a figure for the upper half. There is no selectivity of location of cancer in these two sectors of the lung. Any means which will aid in the discovery of the early occluding lesions should materially reduce the 35 per cent which cannot be accurately diagnosed by the means mentioned. Body section radiography should reduce the remaining 35 per cent.

The underlying principle of body-section radiography has been developed only in the past few years. It consists in employing a properly

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coordinated movement of x-ray tube and film during the x-ray exposure, with the result that a predetermined layer in the body can be radiographed to the more or less exclusion of the structures lying above or below the layer under examination. There are five major types of apparatus invented for this purpose, and there have been simple modifications of some of them. Because of the multiplicity of methods, a general term to include all of them should be used. For this reason, I have strongly urged body-section radiography as the general, inclusive term. It is equally urged that the specific terms be restricted to the particular type of apparatus or principle used. The specific terms used for this method of radiologic examination, in the order of their appearance in the literature, are: stratigraph (Vallebona[1]), planigraph (Ziedses des Plantes[2]), tomograph (Grossmann[3] and Chaoul[4]), laminagraph (Kieffer[5] and Moore[6]), and the biotome of Bocage.[7]

Bocage was the discoverer of the underlying principle of body-section radiography. As far as I can determine, he did not publish a description of his apparatus until 1938. He recommends that an inclusive term be used to cover all the methods of this type of radiographic examination. For this general term he uses the word *radiotomie,* Anglicized to radiotomy, because of its etymological correctness. I agree with Bocage and consider that the Anglicized form, radiotomy, is superior to any other term so far suggested.

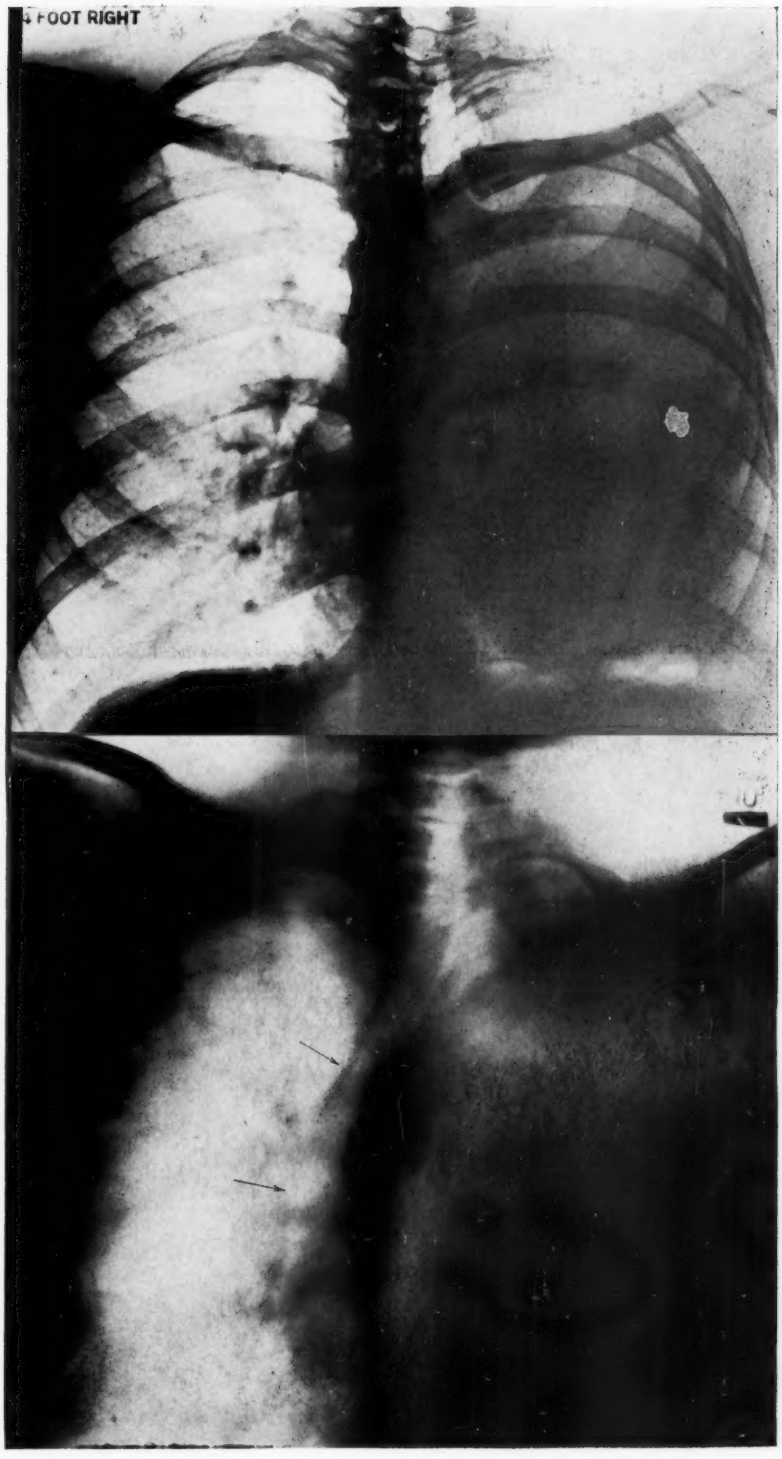
There are also several improvisations for imparting coordinated movement of tube and film for this type of examination. To me it seems unfortunate that the terms planigraphy and tomography are used to describe not only the improvised modification of the principle, but also types of apparatus other than the tomograph or planigraph. In fairness to the investigators in this field of radiography, the indiscriminate use of specific terms for a particular piece of apparatus or method should not be employed to describe another type of apparatus or method from which it radically differs.

In all methods of body-section radiography there is the same objective in view. This is to disperse overlying and underlying shadows and leave a selected layer in the body relatively unobstructed. Another objective is to visualize as thin a layer as possible because minimal contrast in density in such a layer can be brought out. This is called the depth of focus of the apparatus. As a general rule, the more compound the movement of tube and film during exposure, the more efficient the dispersion of unwanted shadows. With simple attachments to standard equipment, body-section radiographs can be made with considerable success. However, the radiographs are inferior to those produced with apparatus of mechanically superior type.

It is not proposed to describe the different types of apparatus used for body-section radiography or to discuss the mechanical and mathe-

A. *B.* *C.*

Fig. 1.—*A*, Conventional film of chest. Opacity of left apex. *B*, Note small bronchial branches visualized in the laminagraph. *C*, Autopsy section of lung shows solid, carcinomatous mass with absence of bronchial branches. (From the *American Journal of Roentgenology and Radium Therapy.*)



A.

B.

Fig. 2.—*A*, Conventional film of chest. Clinical diagnosis: tumor of left lung. *B*, Arrows indicate dislocation of trachea shown in laminagraph.

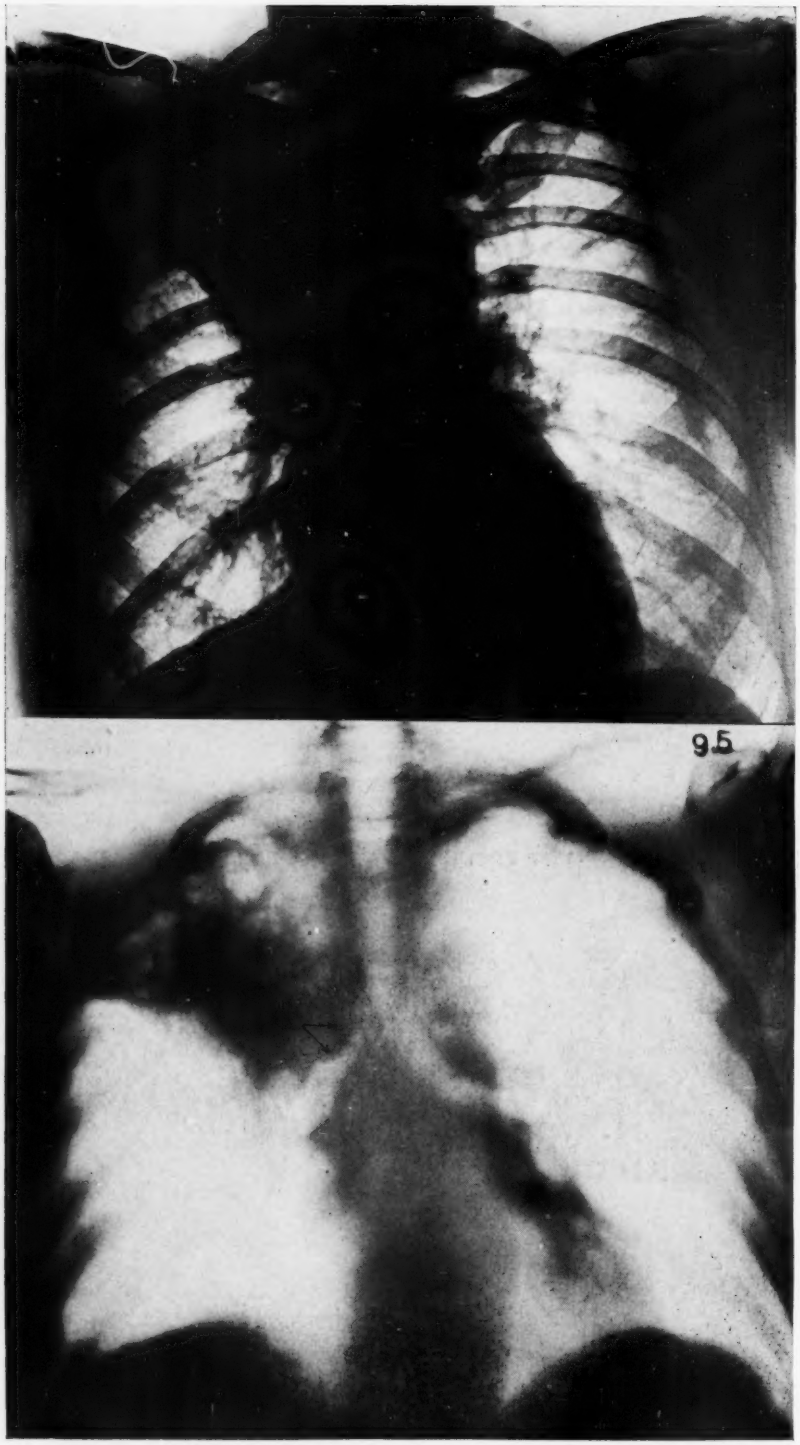


Fig. 3.—*A*, Conventional film of chest. Opacity of right apex. *B*, Laminagraph at 9.5 cm. Arrows point to projection into right main bronchus. Note multiple cavitation periphery of opaque area. Bronchoscopic biopsy: Mixed tumor of lung.

A.

B.

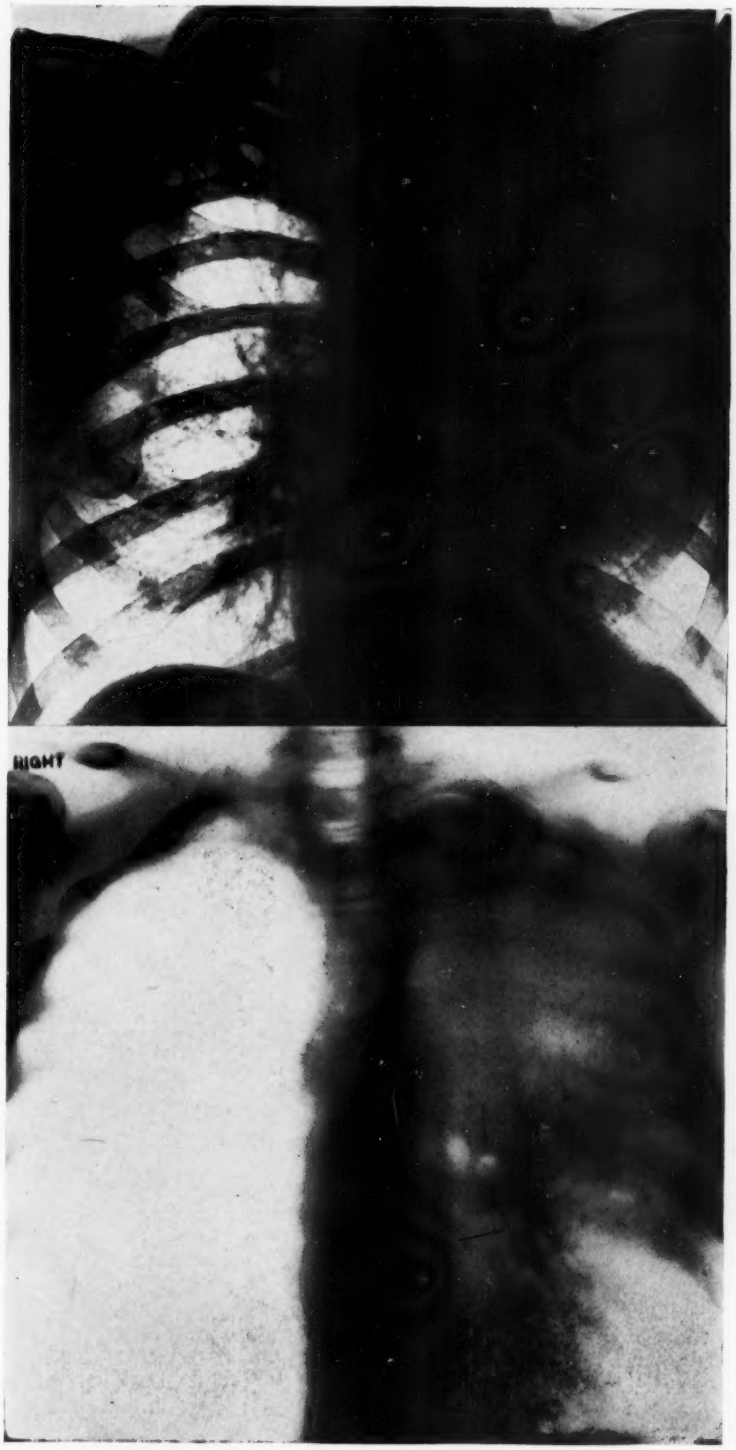
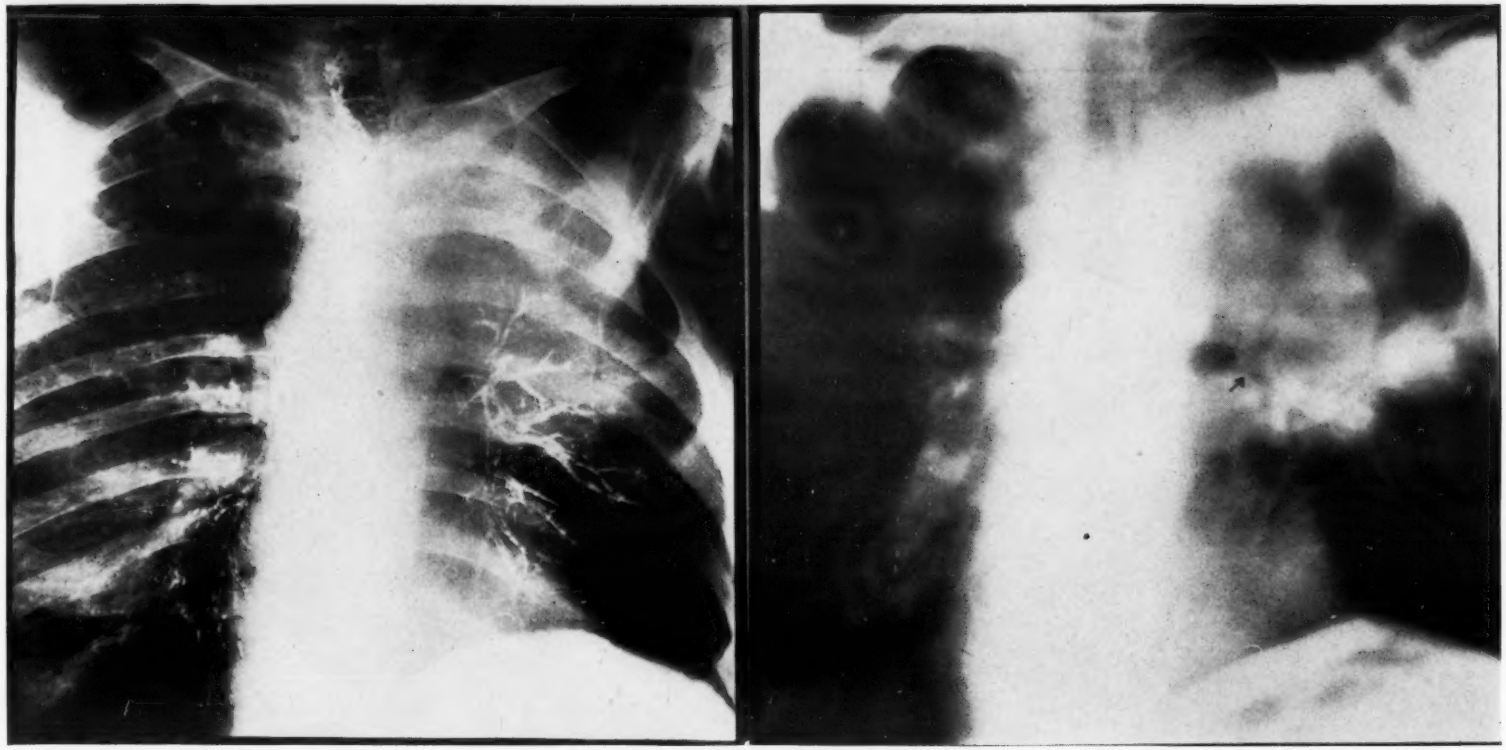


Fig. 4.—*A*, Conventional film of chest. Massive infiltration, upper lobe of left lung. *B*, Laminagraph: Upper arrow points to obstruction of the branch to the upper lobe where it turns posteriorly. Lower arrow indicates lower lobe bronchial branch. Note absence of bronchial branches in opaque area. Uncomfirmed.

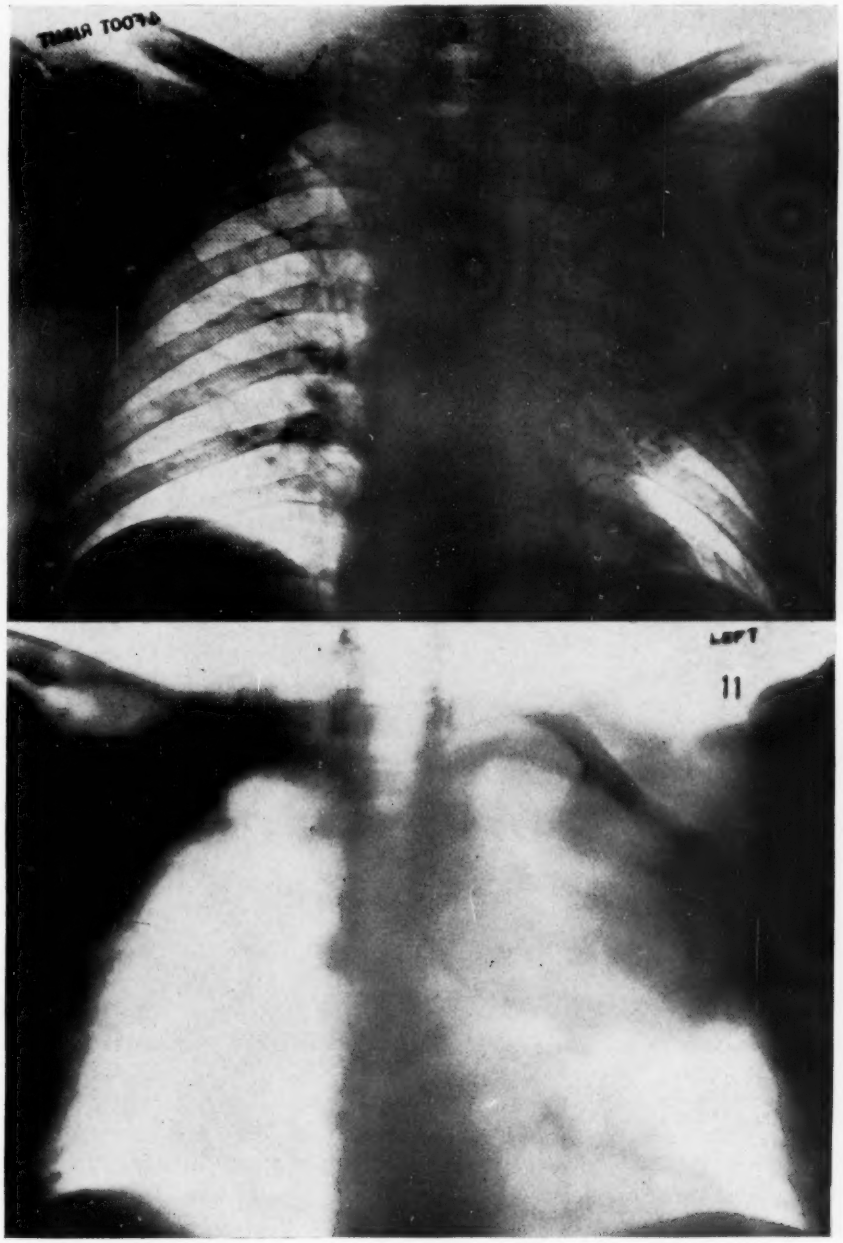


A. *B.*

Fig. 5.—*A*, Conventional bronchography. Incomplete filling of bronchial branches to upper lobe. *B*, Laminagraph. Arrow indicates point of narrowing of bronchial branches. Confirmed by autopsy. (From the *American Journal of Roentgenology and Radium Therapy.*)

matical principles involved. The reader is referred to the publications of Vallebona,[1] Grossmann,[3] Chaoul,[4] Andrews,[8] Kieffer,[5] Moore,[6] Bocage,[7] and others.

From what has been said, it follows that body-section radiography is of greatest use anatomically where there is a maximum superimposition of structures and, on the contrary, is of least value when the oppo-



A.

B.

Fig. 6.—*A*, Conventional bronchography. Incomplete filling of the upper lobe branches. *B*, Laminagraph. Termination of left main bronchus with distal atelectasis. Bronchiogenic carcinoma confirmed by operation.

site is the case. Also, its maximum value would be where there is the minimum amount of density contrast present in the layer under investigation. This applies in pathologic states if a pathologic process produces unwanted shadows which obscure the region under investigation or the process is one which produces only minimal contrast in density.

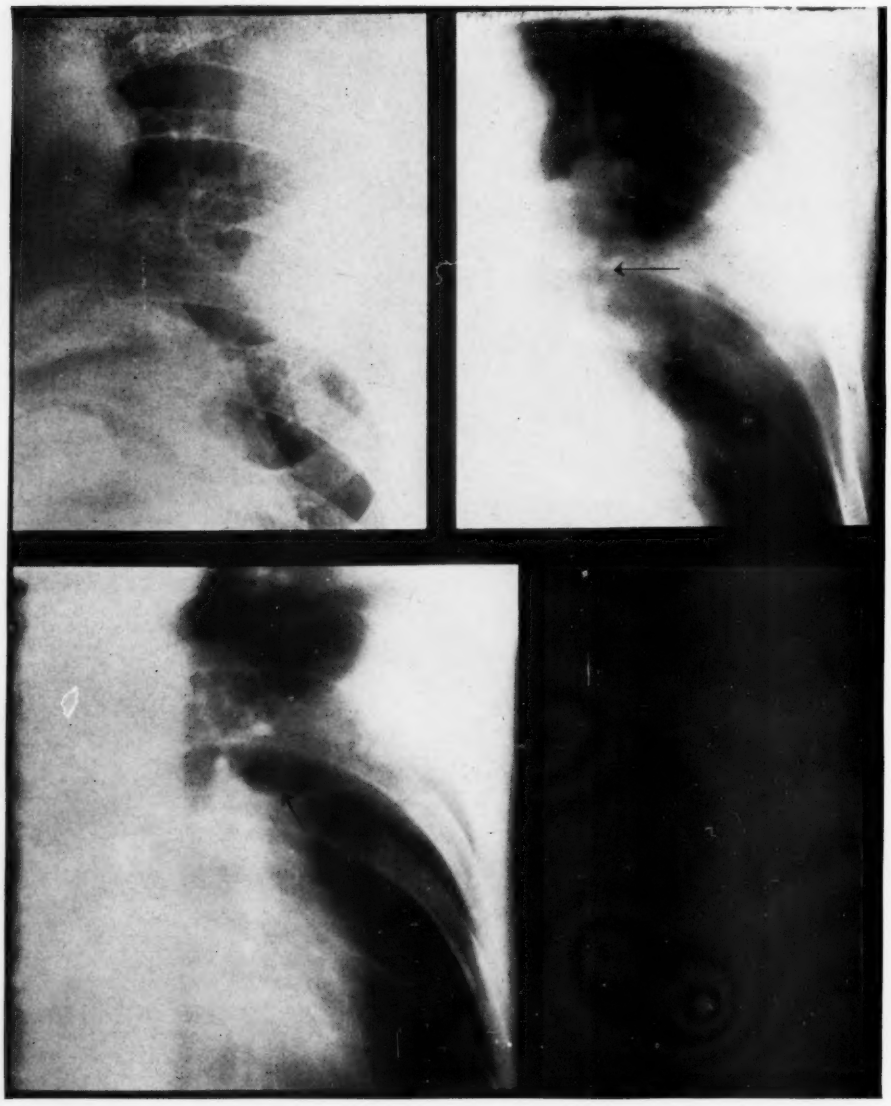


Fig. 7.—*A*, Conventional film of chest. Area of atelectasis in the lung. Arrow indicates termination of bronchus to atelectatic area. *B*, Arrow indicates excavation in the lung. Bronchiogenic carcinoma confirmed by autopsy.

Body-section radiography is of the greatest value in the examination of the respiratory tract. All investigators report it of value in infectious processes of chronic nature of the respiratory tract, particularly in the lungs. The evidence indicates that it is of equal value in neoplastic disease. There is the further advantage of this method of ex-

amination that it may discover malignancy where other methods, such as bronchography and bronchoscopy, or a combination of the two, have failed. The method has been of particular value in the upper portions of the lungs which are always difficult to examine by bronchography and are inaccessible to the bronchoscope. It should be said that body-

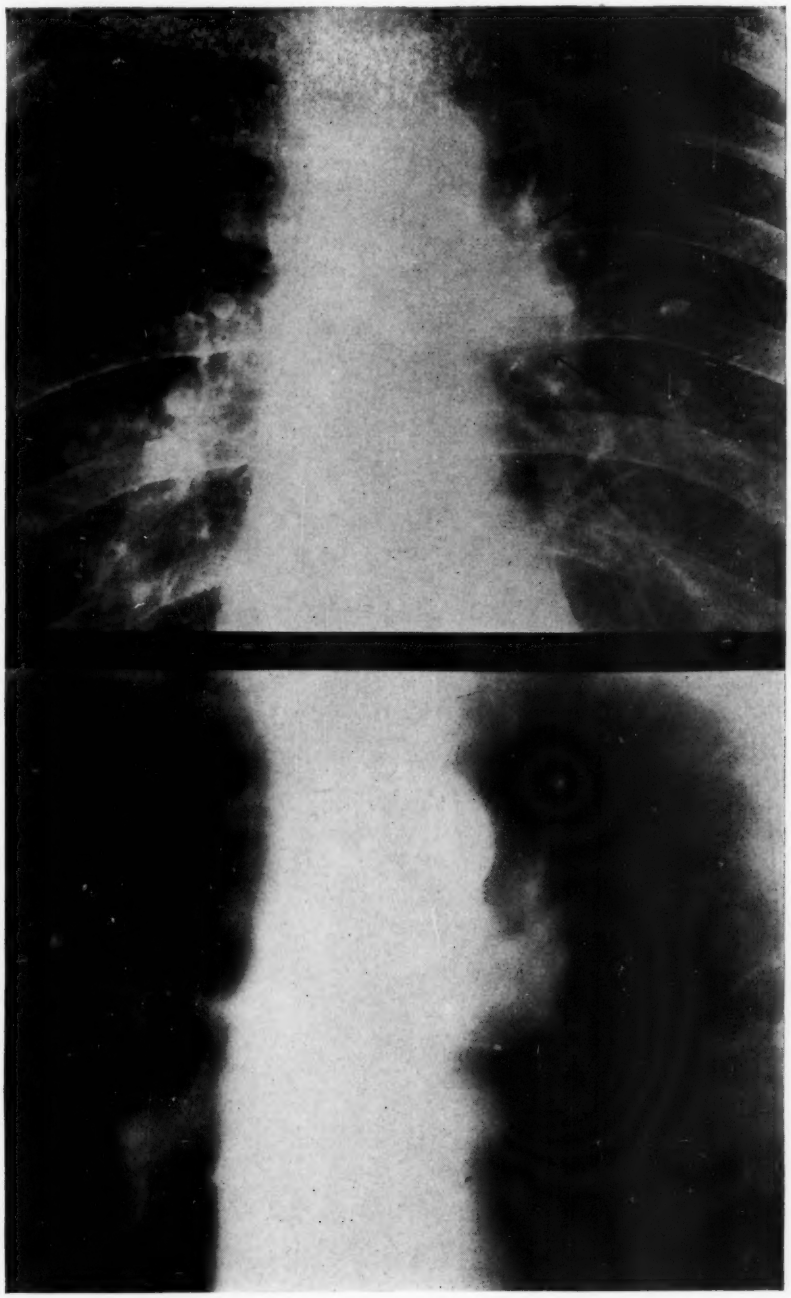


Fig. 8.—*A*, Suspected mediastinal tumor in the left hilus; *B*, laminagraph identifies the suspected tumefaction as the left pulmonary artery.

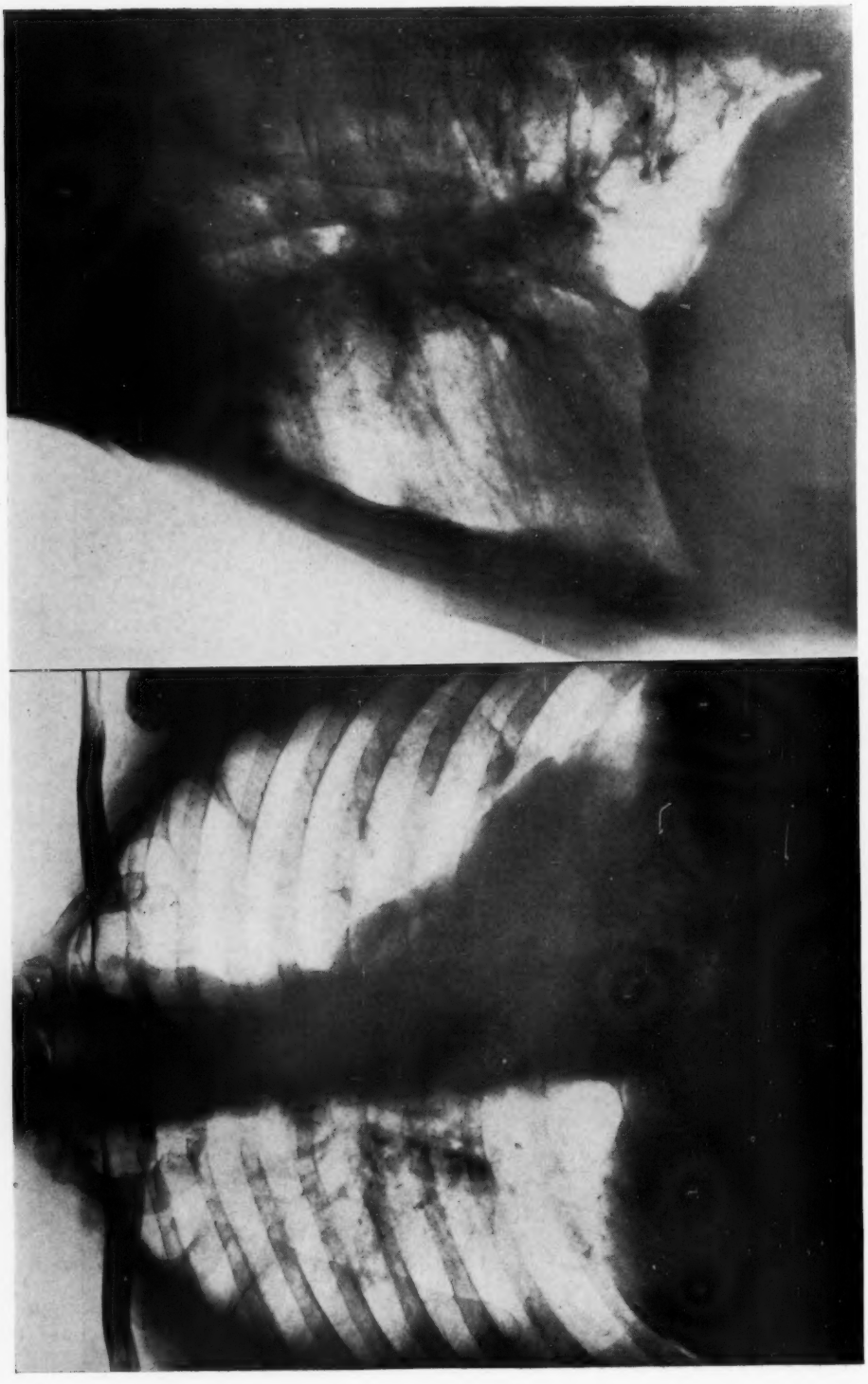


Fig. 9.—Conventional posteroanterior and left lateral films of chest.

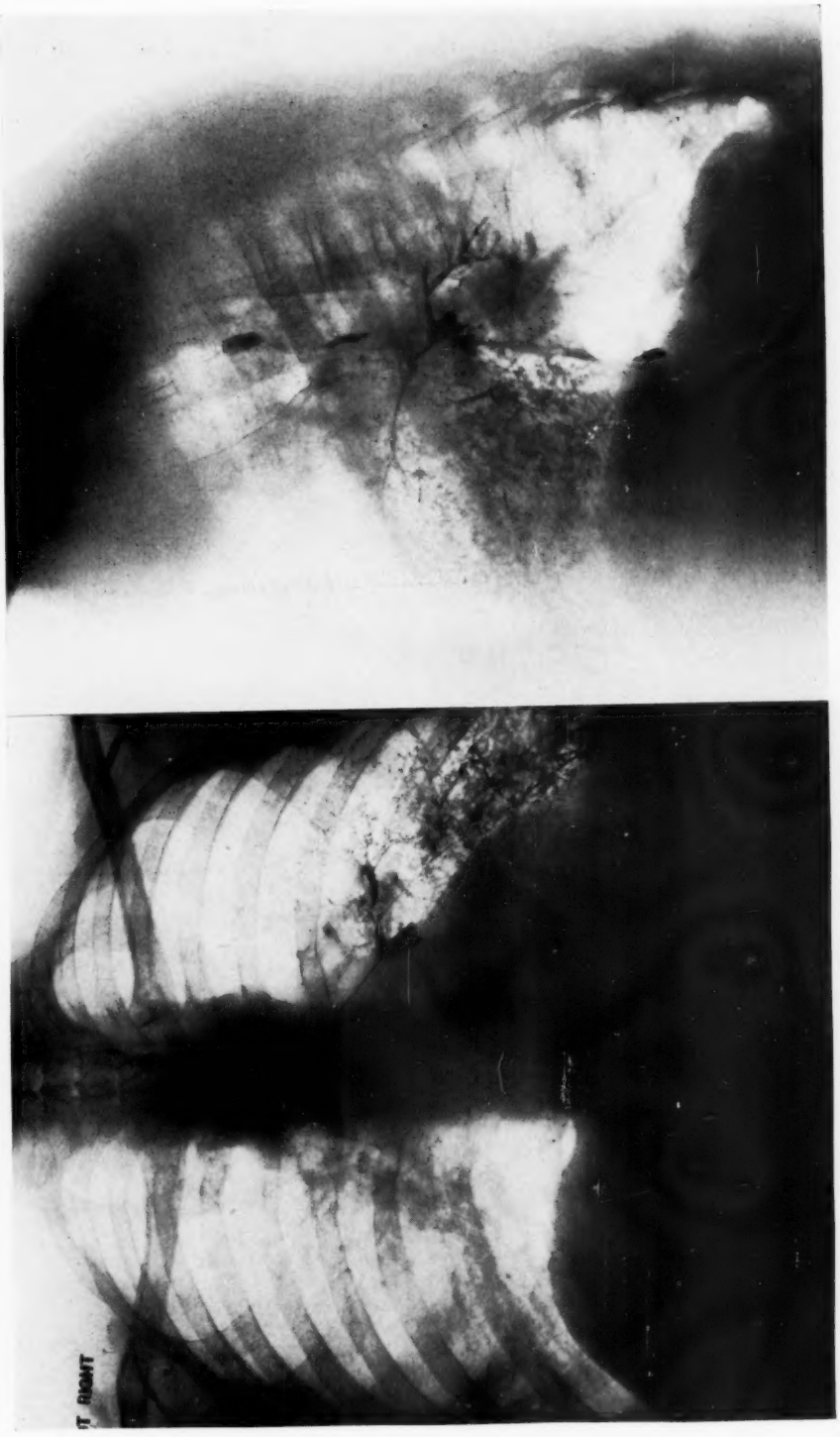


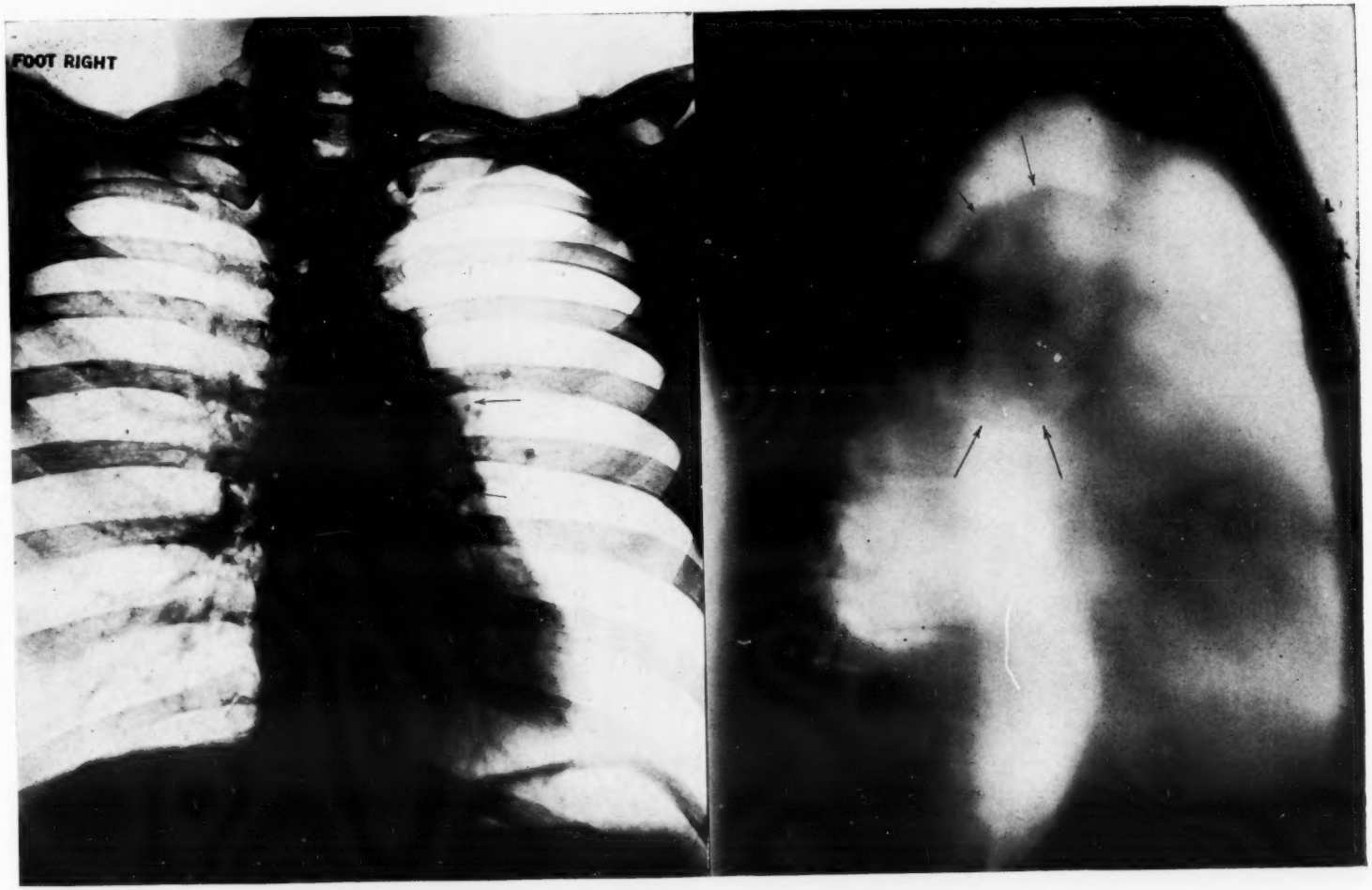
Fig. 10.—Conventional posteroanterior and left lateral bronchography of same patient as shown in Fig. 9. Note termination of descending bronchial branch.

section radiography does not supersede these methods of examination but should be considered as complementary to them.

Laminagraphic examination of the lower respiratory tract can be invaluable in cases where other methods of examination are negative or inconclusive. This presupposes a standard radiographic examination. The suspected area is measured from the film or estimated under the fluoroscope, and a series of laminagrams is made in a ventrodorsal or dorsoventral position, depending on which will put the suspected area nearest the film. For a lateral view, if it is desired, the patient is placed on the side which will bring the lesion nearest the film. Our practice has been to make films at each centimeter of depth through the suspected area. It should be said, incidentally, that the lateral projection is chiefly useful in the investigation of the mediastinum.

Fig. 11.—Laminagraph of same patient as shown in Fig. 9 clearly shows area of infiltration in left lung. Bronchiogenic carcinoma confirmed by lobectomy.

The laminagraph can clearly reveal the tracheobronchial tree, and bronchial branches as small as 3 to 4 mm. in diameter have been shown (Fig. 1). Dislocation (Fig. 2), impingement or distortion (Fig. 3), and termination through obstruction (Figs. 4, 5, and 6) have been clearly shown. It is occasionally possible, by varying the exposures, to separate the vascular and the respiratory tree, but this has not been



A. *B.*

Fig. 12.—*A*, Conventional film of chest. Arrows indicate outline of tumor not visualized on the lateral film. *B*, Lateral laminagraph of chest about at the midline indicates clear-cut tumefaction continuous with the arch of the aorta. Exploratory operation: Tumor mass proved to be an aneurysm of a ductus arteriosus.

done with any great consistency. Intralumenal obstruction from tumor with atelectasis distal to the point of obstruction has been clearly shown. In cases where carcinomatous infiltration has been diffuse, absence of bronchial branches has been shown, and dislocation of branches in the adjacent, healthy lung has also been revealed (Fig. 1). Of course, this applies to what may be termed early cases, or rather, those in which suppuration and abscess formation have not occurred. Very early excavation through abscess formation has been shown in an area of atelectasis in a case of bronchiogenic carcinoma confirmed by autopsy (Fig. 7). Perihilar increase of density, thought to be due to pulmonary tumor, has been shown to be of vascular origin (Fig. 8). Narrowing of a main bronchus through an inflammatory process in its wall has been shown and confirmed by bronchoscopic biopsy. An early bronchiogenic carcinoma (Figs. 9, 10, and 11) confirmed by lobectomy has been shown when there was some doubt following bronchography.

Mediastinal tumors or those near the midline have their true location and their point of origin revealed with suitably made laminagrams. Occasionally in certain standard films of the mediastinum, when a malignant tumor was thought to be present, the laminagraph has revealed an entirely different structure (Fig. 12).

In approximately two years' time there have been ninety-nine tumors of the lower respiratory tract. Of these, twenty-six have been investigated with the laminagraph, the aid from which has been invaluable. There is every reason to suppose that, with growing experience with this method of examination, far earlier diagnoses of malignant tumor of the lower respiratory tract can be made to the consequent benefits of these unfortunate patients.

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BRONCHOSCOPIC DIAGNOSIS OF BRONCHIAL CARCINOMA

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PRIMARY carcinoma of the bronchus has been diagnosed with rapidly increasing frequency during the past decade. Available evidence demonstrates that, although there is an actual increase in the frequency of this disease, accuracy of diagnosis, made possible by the roentgen ray, the bronchoscope, and thoracic surgery, also emphasizes an apparent increase in incidence.[1-3] The bronchoscopic diagnosis of bronchogenic carcinoma is based upon the interpretation of pathology revealed by a direct inspection of the tracheobronchial tree. Thus the bronchoscope is merely a tracheal and bronchial speculum, permitting visual or instrumental examination of otherwise inaccessible portions of the air passages. The purpose of bronchoscopy as an aid in the diagnosis of bronchogenic carcinoma is fourfold: (1) to study the character of the lesion; (2) to note accurately its location and determine its extent along the bronchial walls; (3) to secure tissue for biopsy and thus reveal the exact nature of the growth; and (4) to aid in determining operability by noting evidence or lack of evidence of metastases. These points will be discussed in detail later.

The indications for inspection of the tracheobronchial tree can be listed symptomatically or by the types of pathology elicited by physical examination or x-ray. No physical signs are diagnostic or even characteristic of new growth,[4] but the most frequent symptoms, cough, hemoptysis, or a wheeze, demand thorough investigation to determine the character of the underlying pathology. Obviously, since symptoms depend upon the location and extent of the lesion, they may be entirely absent, as in a very small early lesion on the wall of a major bronchus. Or they may be extensive and still be caused by a relatively small lesion obstructing a major bronchus. As Ochsner and DeBakey[1] state: "There are few or no symptoms in the early course of bronchial carcinoma. . . . Generally, the symptoms are not produced by the neoplasm itself, but are due to secondary changes resulting from its presence."

When roentgen findings suggest bronchial obstruction, otherwise unexplained areas of pneumonitis or gross suppuration, the indication for bronchoscopy is obvious. As Jackson and Konzelmann[5] state, bronchial obstruction is the most cardinal indication for diagnostic bronchoscopy. According to various studies,[6, 7] over 80 per cent of the neoplasms originate in the major bronchi, and it is significant to note the earliest symptoms will not be accompanied by signs of bronchial obstruction which

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could be demonstrated roentgenologically. Westermark[8] says that "cancer of the bronchus does not show directly in the roentgenograms until it is in a very advanced stage." Bronchoscopic examination, therefore, is indicated when symptoms of an unexplained cough, hemoptysis, or a wheeze are present in spite of a negative roentgen examination.[9, 10] Only in this manner can an early diagnosis be made. To wait until the suspicion is confirmed more positively roentgenologically or by means other than direct inspection results in a diagnosis established too late to aid the patient.

Pulmonary suppuration is the second most constant finding associated with an endobronchial neoplasm. The suppuration, in fact, is frequently so predominant that the neoplasm may be entirely overlooked. Findings of a drowned lung, single or multiple lung abscesses, or bronchiectasis are often secondary manifestations of a bronchogenic carcinoma, caused not only by the erosion of the neoplasm, but more frequently by the bronchial obstruction.

Hemoptysis requires as thorough a search for its source as is made by the urologist in cases of hematuria. Gross hemoptysis, of course, definitely contraindicates bronchoscopy. In early lesions with only occasional streaking of sputum, however, the small stream of blood may be followed to its source to reveal the location of the neoplasm. Peripheral tumors may be revealed symptomatically only by occasional slight hemoptyses, vague chest discomfort, or pain due to pleural irritation.

The indispensability of the bronchoscopic examination in all cases of suspected bronchogenic carcinoma and of obscure pulmonary pathology is now well recognized by internists and surgeons. The accuracy of tissue diagnosis and the information gained to determine the operability of the tumor stimulate the bronchologist to study the lesion from a number of aspects.

Character of the Lesion.—Jackson[11] pointed out that there are three types of tumors which manifest themselves by bronchial obstruction: (a) endobronchial, the tumor itself hanging free in the bronchial lumen; (b) peribronchial, the tumor producing a thickening of the bronchial wall, thus producing obstruction; and (c) extrabronchial with endobronchial intrusion, the tumor compressing the bronchus to occlude it partially or completely.

All three types of tumors produce identical symptoms of bronchial obstruction. They manifest themselves physically or roentgenologically by a wheeze, obstructive emphysema, or atelectasis, and direct inspection is necessary to study the character of the growth. These findings are identical to those produced by foreign bodies in the tracheobronchial tree and briefly might be mentioned.

If the lumen of a bronchus is constricted partially, by an intrabronchial growth or by extrabronchial compression produced by a tumor, and air can pass the obstruction on inspiration and expiration, x-ray

findings are negative. On physical examination, however, a wheeze is heard at the open mouth and throughout the chest and is loudest over the point of obstruction. As the tumor grows, the obstruction increases and air becomes trapped in the portion of lung distal to the obstruction, due to the slight increase in the diameter of the lumen of the bronchus on inspiration, which permits air to pass the obstruction. On expiration, the bronchial wall collapses around the tumor, whereby air cannot leave that portion of the lung. The roentgen picture then is negative if the film is taken, as most are, at deep inspiration. A film taken during complete expiration, however, shows a marked shift of the heart and mediastinal structures away from the side of the lesion and a stationary depressed diaphragm on the affected side.

Complete occlusion of the bronchus by the tumor results in atelectasis as the air is absorbed beyond the obstruction. The heart and mediastinum are displaced toward the lesion as they are drawn into the dense atelectatic area to produce the characteristic picture.

Location of Growth and Extent Along Bronchial Walls.—Physical examination and roentgen technique have become so accurate that the exact location of a bronchogenic carcinoma is made frequently prior to direct visualization of the tumor. This diagnosis is reached by determining the degree and extent of bronchial obstruction. Endoscopically, however, the tumor often is found invading the bronchial walls far above the point of complete obstruction. This may be determined only by direct visualization.

Biopsy.—The most important function of the bronchoscope in establishing the diagnosis of bronchogenic carcinoma is the obtaining of tissue for biopsy. Sufficient tissue in the majority of cases can be removed with forceps to permit satisfactory study and classification of the tumor. In this manner an increasingly high percentage of cases is correctly diagnosed. In a series of 300 cases, Kramer and Som[12] proved the diagnosis by bronchoscopic biopsy in 222, or 74 per cent. Clerf[13] obtained a positive tissue diagnosis in 98, or 68.5 per cent, of 143 proved cases of bronchogenic carcinoma. In Jackson's[14] statistics bronchoscopic biopsy was possible in about 75 per cent of the cases of bronchial carcinoma, and Overholt[10] obtained a specimen for microscopic study in 28 of the 32 cases of his series.

The bronchoscopic picture is extremely variable. In early lesions a small stream of blood may lead to an eroded area from which tissue may be removed to reveal the identity of the tumor. The blood itself is aspirated, collected, centrifuged, fixed, and sectioned. It occasionally establishes the diagnosis when the tumor itself is too small or too deep in the periphery to be reached with forceps.

More frequently, however, the bronchoscope demonstrates a verrucous, friable, soft mass completely obstructing the lumen of one of the main bronchi. It occasionally is covered with exudate. Tissue easily can be

teased off this mass with forceps used for removing ball bearings or beads from the air or food passages.[5] These forceps are preferred to the sharper cutting type because they cause less bleeding. Should the tumor be very firm or infiltrated, there is no contraindication to the use of the cutting or tissue-biopsy type of forceps.

The more advanced type of lesion is accompanied by copious quantities of sanguinopurulent secretion. The bronchi are distorted, the walls irregular and freely bleeding, and the true obstruction is a friable mass. Large pieces of tissue can be removed for biopsy and the patient relieved temporarily by aspiration of the putrid material beyond the obstruction. In these cases, however, as Lederer[15] suggests, the element of danger from hemorrhage must be kept in mind. Occasionally at this stage the destruction of tissue confuses the picture by profuse bleeding, pus, and granulation tissue. Repeated bronchoscopies may be necessary to get tissue representative of the tumor itself and not alone of the peripheral inflammatory zone[5] to establish the diagnosis.

Special endoscopic problems arise from tumors in the upper lobe bronchi. Should an atelectasis of an entire upper lobe occur, the tumor in many instances protrudes from the upper lobe orifice. As the upper lobe bronchus leaves the main bronchus on the right side at an angle of 90 degrees and on the left side at about 70 degrees, however, a tumor 1 cm. within the orifice seldom can be inspected directly, especially because the bronchial walls are made rigid by neoplastic involvement and in many instances will not permit gentle manipulation with the lip of the bronchoscope to give adequate exposure. These angles, furthermore, are made more acute if the lobe beyond the point of obstruction is atelectatic, thereby tending to pull the bronchus further toward the apex. Thus other aids, such as an artificially induced pneumothorax, are needed to release the distorted bronchus and bring it further into the direction of the main bronchus, facilitating its entrance with the bronchoscope. This procedure was used by Arbuckle to obtain the biopsy in what later proved to be the first case of successful pneumonectomy for bronchogenic carcinoma.[16]

Inspection of the upper lobe bronchi is facilitated further by the use of a retrograde telescope or retrograde mirror. The use of these instruments is hampered by the condensation of moisture on the glass surfaces. By heating them thoroughly first or coating the surfaces with special oils, very satisfactory observations may be made.

Fluoroscopy as an adjunct to the bronchoscopic procedure is routinely used in dealing with certain types of bronchopulmonary foreign bodies. This is especially true in dealing with foreign bodies in the periphery of the lung where the bronchi become so small that the use of bronchoscopes with lumina large enough for direct vision is impossible. Biplane fluoroscopy is then indispensable. Too, it may aid in guiding forceps into the

costophrenic angles or upper lobe bronchi in search of tumor tissue for biopsy when the tumor lies in a branch bronchus beyond the scope of direct vision.[17]

Failure to obtain a positive biopsy in cases later proved, either surgically or at post mortem, to be bronchogenic carcinoma frequently may be attributed to the nature of the malignancy. The rigidity of the bronchial tree or the trachea adjacent to a tumor may make it impossible to advance the bronchoscope to the endobronchial portion of the tumor. If the bronchial compression of a tumor collapses a bronchus proximal to the endobronchial invasion of that tumor, biopsy cannot be obtained without danger of penetrating pulmonary tissue. The deformity and rigidity, of course, help indicate the clinical diagnosis of cancer,[14, 18] and add to the information gained from x-ray and physical examination in establishing the diagnosis.

Aid in Determining Operability.—Bronchoscopy may be repeated if findings of questionable significance present themselves,[19] or if the biopsy reveals no positive tissue. But valuable time should not be lost waiting for endobronchial evidence of a tumor if other features strongly indicate a malignancy.

Besides actually inspecting the endobronchial tumor and noting its character, exact relationship to surrounding structures, and its extent along a bronchial wall, certain features in the bronchoscopic appearance of the remainder of the tracheobronchial tree are of great importance. As Jackson and Konzelmann[20] state: "Perhaps a little too much emphasis has been placed upon positive biopsy in the past. Certainly biopsy material, when obtainable, should be carefully studied, but we must not concentrate our attention so closely on biopsy as to neglect the other aspects of the bronchoscopic and clinical picture. If the accessible portions of the tracheobronchial tree are found entirely negative, so much the better; the surgeon knows that in such a case he can amputate any of the larger bronchi and not leave tumor tissue behind, though he must proceed with no knowledge of the histopathologic character of the lesion and rely solely on the clinical diagnosis." Enlargement of mediastinal glands is detected by a thickening at the division of the trachea. This area, the carina, is usually sharp, regular, and freely movable. With mediastinal metastases, the carina becomes thickened, irregular, and fixed. Should these findings be present, lobectomy or pneumonectomy, of course, is contraindicated.

Direct or indirect inspection of the larynx frequently gives valuable correlative information. Hoarseness, produced by a paralysis of the left recurrent laryngeal nerve as it passes under the arch of the aorta, is almost always present in late, left-sided bronchogenic carcinoma. It is not an infrequent early sign and has occasionally been the first symptom of which the patient complains. Paralysis of the right vocal cord, a much less frequent finding, indicates, in cases of apical tumors on the

right side, that invasion or compression has progressed to a point under the right subclavian artery. This again corroborates evidence of extension.

Another important role of bronchoscopy in relation to bronchogenic carcinoma is the establishing of the differential diagnosis. Any type of bronchial stenosis, whether produced by tuberculosis, foreign bodies, or bronchiectasis must be considered.[21] An inflammatory lesion, such as a lung abscess, may be accompanied by marked proliferation of granulation tissue. Bronchoscopically removed tissue from this area is the only method of establishing whether the abscess is secondary to a carcinoma or is entirely inflammatory in character.

Tuberculosis, often most difficult to diagnose, especially in its incipient stage, may produce symptoms of cough, hemoptysis, and loss of weight which are sufficient to make the diagnosis of tuberculosis, in spite of a negative chest x-ray or sputum examinations repeatedly negative for tubercle bacilli. Bronchoscopically aspirated secretion may show the bacilli, but, what is more important, an early carcinoma may be discovered. Only by making early differential diagnoses can cases favorable to surgery be discovered.

Benign tumors of the bronchus offer another problem in diagnosis which can be settled only by microscopic examination of the tissue. The bronchoscopic appearance of a benign lesion is frequently quite characteristic, but, as in dealing with any tumor, the gross appearance can be relied upon only in a small percentage of cases.

Bronchoscopic Therapy.—A remarkable disproportion exists, as Clerf[13] states, between the large number of reported cases of primary carcinoma of the bronchus and the small group that has been successfully treated. The surgical excision of a carcinoma is recognized as the therapeutic procedure of choice when feasible. The growing list of patients treated successfully in this manner represents a surgical advance only in the experimental stage a little more than five years ago. Certain endobronchial tumors fall into a borderline classification that, though histologically frequently reported as carcinomatous, clinically reacts as benign growths. The bronchoscopic treatment of these tumors, as well as frank malignant growths otherwise inoperable, initiated an interesting phase of bronchology directed toward the re-establishment of the bronchial lumen and efforts to keep it patent.

Forceps removal of a benign bronchial tumor was described first by von Eicken in 1907.[22] Later Jackson [23] removed a tumor from the right main bronchus by the same method. The tumor removed by von Eicken was considered benign; that removed by Jackson was regarded, pathologically, as malignant. The forceps removal of tissue obstructing a bronchus is a practical, rapid method of re-establishing the lumen. The control of hemorrhage is difficult with this technique, however; consequently, it has been supplanted to a large degree by the use of surgical

diathermy. Vinson and Bowing[24] first described the value of this type of therapy which, in certain selected cases, is of definite value in the treatment of primary carcinoma of the bronchus.[14, 25, 26]

A more recent type of endobronchial therapy directed bronchoscopically is the implantation of radon seeds or radium directly into the obstructing tumor. Although the results have been palliative in most instances, a few exceptions should be mentioned. Negus,[27] Kernan,[25] Ormerod,[28] and others have reported clinical cures by the use of this method together with the use of surgical diathermy. It should be noted that in most of these cases the biopsy revealed the tumor to be an adenocarcinoma.

The bronchoscopic insertion of tubes containing radon has been suggested by Soulas,[29] von Eicken,[30] Negus,[27] and others. More recently, Pressman and Emery[31] have devised an applicator for the implantation of radium needles directly into the bronchus to remain in place thirty to sixty-five hours. A preliminary pneumothorax was of definite advantage in this latter type of therapy.

Clinical cures of bronchogenic carcinoma through the use of any or all of these bronchoscopically directed methods of therapy are significant and frequent enough to suggest their use in selected cases otherwise inoperable.

CONCLUSIONS

1. The purpose of bronchoscopy as an aid in the diagnosis of bronchial carcinoma is fourfold: (a) to study the character of the lesion, (b) to note its location and extent along the bronchial wall, (c) to secure tissue for biopsy if the tumor can be visualized, and (d) to aid in determining the operability of the tumor.

2. Bronchoscopic examination of the tracheobronchial tree is an indispensable aid in establishing the differential diagnosis of pulmonary pathology.

3. The treatment of bronchogenic carcinoma, primarily surgical in suitable cases, may be carried out endoscopically in certain instances by the use of electrocoagulation, radon, or radium implantation. Although several recoveries have been reported by these methods, they are, for the most part, palliative.

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DIAGNOSIS OF MALIGNANT LUNG TUMORS BY ASPIRATION BIOPSY AND BY SPUTUM EXAMINATION

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A CARDINAL principle today in the treatment of malignant tumors is that a biopsy demonstrating the presence of a malignant tumor should be obtained if possible before radical treatment is instituted. In the case of certain deeply situated tumors it may be difficult by ordinary means to secure a biopsy. Cancer of the lung furnishes an example of the difficulties which a clinician may encounter when he wishes to obtain histologic proof of the malignant nature of a tumor before subjecting the patient to radical treatment.

To those who have had a true cross-sectional experience in diagnosing cancer of the lung, it is perfectly obvious that histologic proof is the only proof of this disease. There is no roentgenologic or bronchoscopic appearance that in itself can be claimed to be pathognomonic of cancer of the lung. A strong suggestion, or even a near certainty, of a diagnosis of cancer of the lung, based on the appearance of routine roentgen films, tomograms, lipiodol films, or fungating ulcerated lesions seen through the bronchoscope, cannot compare with the assurance gained by identifying cancer on a microscopic slide, when it comes to deciding for or against pneumonectomy or intensive roentgen therapy. Either the modern surgical or the modern radiological treatment of cancer of the lung is such a radical procedure, and so hazardous to the patient, that it should not be undertaken without good evidence of its necessity.

A belief that early diagnosis of a very high proportion (90 per cent) of primary carcinomas of the lung should be possible by means of the bronchoscope can only reflect an experience that is one-sided and that has missed some aspects of the disease. There is even a considerable group of bulky hilar or mediastinal tumors, primarily bronchiogenic, which on routine roentgen examination would seem to offer every likelihood of positive bronchoscopic biopsies, yet which may present completely negative findings bronchoscopically. There is certainly a large group of primary bronchiogenic carcinomas, increasingly recognized now, in which the lesion lies far out in the lung field or in the upper lobe, beyond accessibility for bronchoscopic biopsy.

Confronted with such examples of bronchoscopically inaccessible lung tumors, the thoracic surgeon in general is inclined to explore through a thoracotomy. This procedure requires admission of the patient to a hospital and subjects him to the risks of a major operative undertaking.

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Since a large proportion of cases of lung cancer are inoperable as far as lobectomy or pneumonectomy is concerned, the routine practice of thoracotomy to establish a diagnosis of cancer involves major surgery for many patients for whom there can be offered no hope that the surgeon, finding cancer, can then go on and remove the diseased lung. In cases with pleural effusion, thoracoscopy to determine the presence of pleural metastases may be advisable as a relatively minor procedure, safeguarding against an unwise decision to attempt major operative attack on the disease. Examination of sedimented or centrifuged pleural exudates is notoriously unreliable in making a diagnosis of cancer of the lung. A biopsy of a swollen lymph node may show that the patient has a primary carcinoma arising somewhere within the drainage area of that node, but it is almost the rule that the pathologist cannot determine certainly whether the structure means origin from lung. In rare instances the patient may cough up a piece of tissue that will furnish proof of bronchiogenic carcinoma.

In view of the foregoing premises, and in view of our experience in other fields with the successful practice of aspiration biopsy, the staff at Memorial Hospital began over a decade ago to apply aspiration biopsy to the field of lung tumors, feeling that in this procedure we possessed a means of obtaining a diagnosis quickly, with comparatively little discomfort or danger to the patient, and particularly without subjecting inoperable cases to a major operation, thoracotomy.

A recent survey of our files for carcinoma of the lung yielded 175 cases regarded as proved histologically, from a total of 401 cases (Table I). It is probable that most of the 226 unproved cases were cases of carcinoma of the lung, too, but in them histologic proof is lacking.

In Table I it will be noted that after 1932 the number of proved cases for the first time, and steadily thereafter, exceeded the number of unproved cases. While this increase in proportion of proved cases no doubt in some measure has been due to improved use of the bronchoscope, in probably a larger measure it has been due to increased familiarity and success with the technique of aspiration biopsy. This statement may be illustrated by Table II, which compares by years the use of the three leading methods of obtaining in our series a diagnosis of cancer of the lung, these methods being thoracotomy, bronchoscopy, and aspiration biopsy.

In Table II it will be noted that, beginning with one case in 1927 and with increased frequency since 1934, it has appeared necessary to resort to aspiration biopsy to obtain the diagnosis.

In Table III is presented a summary of the methods relied upon for diagnosis in preparation for treatment in the 175 cases in our series regarded as proved cases of bronchiogenic carcinoma. These methods are listed in the order of likelihood of certainty of proof.

TABLE I

CARCINOMA OF LUNG FILE, MEMORIAL HOSPITAL

YEAR	UNPROVED CASES	PROVED CASES	TOTAL
1918	4	0	4
1919	8	0	8
1920	5	1	6
1921	9	1	10
1922	16	0	16
1923	6	1	7
1924	5	3	8
1925	14	1	15
1926	13	1	14
1927	9	2	11
1928	17	3	20
1929	9	2	11
1930	9	8	17
1931	15	10	25
1932	21	9	30
1933	14	18	32
1934	14	20	34
1935	13	21	34
1936	9	20	29
1937	3	21	24
1938	9	24	33
1939 (to July 1)	4	9	13
Totals	226	175	401

TABLE II

COMPARISON OF USE BY YEARS OF THREE LEADING METHODS OF INTRAVITAM DIAGNOSIS OF BRONCHIOGENIC CARCINOMA*

	THORACOTOMY	BRONCHOSCOPY	ASPIRATION BIOPSY
1920	0	1	0
1921	1	0	0
1922	0	0	0
1923	1	0	0
1924	1	1	0
1925	1	0	0
1926	0	1	0
1927	0	1	1
1928	1	1	1
1929	0	2	0
1930	0	4	1
1931	0	6	3
1932	0	5	3
1933	0	11	3
1934	2	12	3
1935	0	10	9
1936	0	8	10
1937	0	4	15
1938	0	9	13
1939 (to July 1)	1	4	2
Totals	8	80	64

*It should be noted that only one of the thoracotomies was done at Memorial Hospital. All the rest were done elsewhere, before the patient was referred to this hospital.

TABLE III

MODES OF INTRAVITAM DIAGNOSIS (IN PREPARATION FOR TREATMENT) OF 175 CASES OF PRIMARY CARCINOMA OF LUNG

	NO. OF CASES
Thoracotomy	8
Expectorated tissue (added confirmation by this means in 2 cases)	0
Bronchoscopy	80
Aspiration biopsy from lung	64
Aspiration biopsy from rib (directly invaded by the lung tumor)	1
Excision or aspiration biopsy of lymph nodes (added confirmation by this means in 5 other cases)	7
No tissue during life (all subsequently confirmed by autopsy)	15
Total	175

It will be noted in Table III that in 64 cases, or 36.6 per cent, the intravitam diagnosis was based on aspiration biopsy from the lung. By reference to Table IV it may be seen that in the years 1935 to July 1, 1939, aspiration biopsy accounted for 51.6 per cent of all the cases regarded as histologically proved.

TABLE IV

ASPIRATION BIOPSIES VS. BRONCHOSCOPIES (1935 TO 1939)

	ASPIRATION BIOPSY	BRONCHOSCOPY	OTHER METHODS OR PROVED ONLY BY AUTOPSY	TOTAL
1935	9	10	2	21
1936	10	8	2	20
1937	15	4	2	21
1938	13	9	2	24
1939 (to July 1)	2	4	3	9
Totals	49	35	11	95
Percentage	51.6	36.8	11.6	100.0

MODES OF APPROACH TO DIAGNOSIS OF CANCER OF THE LUNG

In setting about to confirm histologically a diagnosis of cancer of the lung, certain preliminary examinations are quite essential. First of all, a careful history should be taken, noting as accurately as possible the chronology of symptoms and any etiologic factors that could be considered to have a bearing on the case. The usual complete physical examination is important, particularly with reference to signs of metastases or extensions of the disease. Such points as palpable tracheal deviation, supraclavicular or axillary lymph node metastases, tumefaction of invaded ribs, Horner's syndrome, signs of fluid, cutaneous or distant lymph node metastases (as to the inguinal nodes), signs of bone metastases, and dilated veins on the chest wall, should be particularly observed and noted.

The usual next step is to obtain a posteroanterior erect chest film at 2 M. distance. If on the basis of signs it is possible to localize the

lesion as being unilateral, a straight lateral view, with the film on the affected side, is made at the same time. A preliminary fluoroscopy may be of considerable aid in determining which views to make, and barium swallowing may be indicated in some cases to aid in ruling out esophageal primary lesions; in demonstrating external pressure on the esophagus by a tumor of the lung; or to aid in excluding aneurysm, cyst, or other causes of intrathoracic tumefaction.

If the lesion as portrayed roentgenologically seems not entirely inconsistent with bronchiogenic carcinoma and the history and physical findings also lend support to that diagnosis, the usual next step is bronchoscopy. We now usually prefer to do bronchoscopy in all cases suspected in any way of being cases of cancer of the lung, even though the appearance of the films may not make it seem likely that the lesion will be accessible to the bronchoscope. We do so because occasionally, even in such cases, the bronchoscopist may obtain a positive biopsy, or at least may give helpful information about such points as the presence and location of bronchial distortion or fixity or the presence of blood or pus in the bronchial tree. Another motive at present is, frankly, a desire to put on record additional cases of proved cancer of the lung in which bronchoscopy cannot obtain a positive biopsy, in order to be able to aid in establishing a better general concept of the problems involved in making a diagnosis.

Naturally, if bronchoscopy yields a positive biopsy, the diagnosis can be regarded as made with reasonable certainty and aspiration biopsy need not be employed. To give proper credit to bronchoscopy, it must be said that, in general, the positive biopsies so obtained can be interpreted more readily as to grading of degree of malignancy and as to cell type than can be done with the immediate smears of material aspirated from a lung tumor by a needle. On the other hand, however, sectioning of the clot frequently obtained in the process of aspiration biopsy may yield histologic sections of a much better quality than the crushed scrapings which are all that may be obtained in some cases by bronchoscopy, and in some instances these clot sections are indistinguishable from regular sections such as are obtainable by thoracotomy or from autopsy material.

If, as so often happens, despite unimpeachable technique, no positive biopsy can be obtained by the bronchoscopist, we then have to consider whether it is feasible to do an aspiration biopsy. This problem is comparatively easy in the case of bulky peripheral masses, especially those that are well delimited and look solid. In these cases it is easy to select the best site for insertion of the needle, and, in fact one may have a choice of more than one approach. In many other instances, however, more information is needed about the best site for aspiration than is available from routine chest films alone, and this information may have to be built up from several sources. One has first to review

the bronchoscopist's notations as to the site of distortion of a bronchus, or the finding of pus or blood that came from a particular branch of the bronchial tree, together with a reconsideration of the chest film, with special reference to how much of the shadow may represent tumor and how much may be caused by atelectatic and inflammatory changes peripheral to the tumor. At this stage lipiodol injection may be very helpful, if it has not already been done. The contour of shadows in well-made lipiodol films, demonstrating bronchial blockage, may be of great service in indicating a likely site for lung puncture. We have not thought it necessary to produce a pneumothorax, in general, and in fact it seems to us more probable that a pneumothorax would in many cases obscure the relations and make it more difficult to localize the tumor.

The old roentgenologic riddle of aneurysm versus mediastinal tumor has caused us much difficulty in several instances. The interpretation of expansion of a mass by fluoroscopy or kymography, together with the aids of tomography and Robb's method of arteriography, all may be called upon in some instances, with, nevertheless, equivocal findings. The double-tube method of fluoroscopic localization, apparently so foolproof for foreign bodies, would seem to be too hazardous for use for lung aspiration about the hilar fields, involving, as it does, the visualization of a double image of everything in the field, including the needle and the aorta. It has been proved possible in our experience to go into the hilar field under fluoroscopic guidance, in one case passing the needle within 1 or 2 cm. of the left auricle and obtaining a positive biopsy without perceptible harm to the patient. We certainly, however, do not recommend such a procedure routinely, nor would we undertake it save in exceptionally favorable circumstances.

When there are signs of lung abscess the question always arises whether it is safe to do an aspiration biopsy, for fear of spreading infection along the puncture tract. We have successfully performed aspiration biopsy of both cancerous and noncancerous abscesses of the lung in several instances, without, so far as we have been aware, causing any complication. We have never observed empyema following aspiration biopsy. Neither have we ever seen a growth of tumor along the needle tract.

There are certain cases in which it is impossible to determine an optimum site for puncture. The shadow of increased density in the lung field may be large and ill defined and it may be impossible with the aid of lipiodol to judge whether the tumor is likely to be found permeating the entire area of increased density; whereas, if one assumed that the tumor were confined mainly to the medial zone of the area, it would lie in an area too close to heart or aorta or hilar or mediastinal structures to be aspirated safely. In such cases one is justified in selecting arbitrarily what is deemed to be a safe site for punc-

ture in the middle of the area of increased density and in several such cases positive biopsy has been obtained from such "blind" aspirations.

If there is an accessible metastatically involved lymph node, it seems good practice to remove it or at least to obtain an aspiration biopsy from it first, so as to prove the existence of cancer; but it is often difficult for the pathologist to state conclusively whether cancer so identified is of lung origin. If there is a bone lesion, apparently of metastatic origin, or a rib lesion, apparently a direct extension of the lung tumor, an aspiration biopsy of the affected portion of the bone may yield a diagnosis of cancer. Here again it is not entirely satisfactory to rely upon such evidence for proof of primary lung cancer. Since it has been shown that inflammatory pleural effusions may yield clumps of pleural mesothelial cells closely simulating cancer, it is obviously unwise to rely on a diagnosis based, as far as histologic evidence is concerned, solely on the apparent finding of cancer cells in pleural fluid.

As far as proof of primary lung origin is concerned, the same criteria must be applied in large measure to cases with bronchoscopic biopsies as to those with aspiration biopsies, since it is quite possible (and we have observed this in more than one instance) for metastatic lung tumors to erode the bronchial wall. For practical purposes we may decide that a given tumor is primary in the lung if the biopsy is obtained from the lung or bronchus and if there is no evidence of the previous or present existence of a primary tumor elsewhere that would be capable of causing a lung metastasis. However, for absolute proof of primary lung origin, we must demand an unqualified demonstration of that fact both grossly and microscopically by an experienced tumor pathologist at autopsy.

THE TECHNIQUE OF ASPIRATION BIOPSY

Since fear of air embolism (see below) has led to an abandonment whenever possible of the performance of aspiration biopsy of the lung with the patient sitting up, it is now routine practice to localize the tumor fluoroscopically with the patient fully recumbent, in prone, supine, lateral, and oblique positions, and to mark the site of puncture with the patient in the same position that he will be in during the puncture. In the case of small tumors it may be necessary to use fluoroscopic guidance in the course of the aspiration procedure. To this end a biplane fluoroscope of special design would be of great aid. Such a fluoroscope should have no encumbrances about the patient, as is true of the present standard biplane fluoroscopes. The horizontal tube should be 3 to 4 feet away from the patient, and the tube for the vertical beam should be under the floor or at least on the floor so that it will be sufficiently far away to do away largely with distortion. We have not had the advantage of such specially made biplane apparatus, of which there are only a few in existence. When we were doing

aspirations with the patient in the erect posture, sitting on a revolving stool, we obtained a biplane examination by very cautious rotation of the patient on the stool after the needle had been inserted as best we could with the guidance of fluoroscopy in one plane. If the straight posteroanterior and the straight lateral views both demonstrate the point of the needle to lie opposite the center of the tumor, the point of the needle must be actually in the center of the tumor.

However, with a patient recumbent, we do not dare risk moving or rotating his body while a needle is in it. That is where a biplane fluoroscope free of encumbering rods and supports for screens would be of

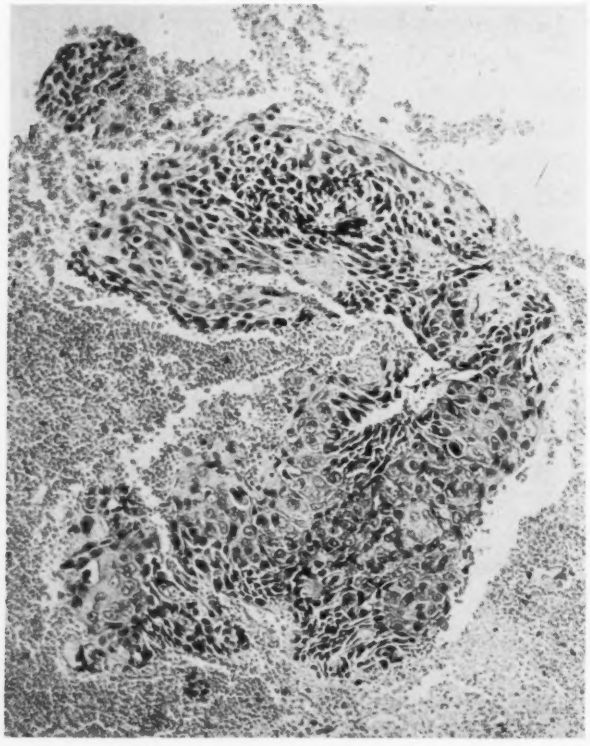

Fig. 1.—Section of clot obtained by aspiration biopsy from tumor shown in Fig. 2. The immediate smear was also quite diagnostic.

great help. Since the abandonment of the erect posture and the performance of all lung aspirations with the patient recumbent or in slight Trendelenburg position, we have had to rely on straight posteroanterior fluoroscopy, plus previous measurement of the depth of the center of the tumor from the skin at the site of the puncture. If the tumor is of more than 5 cm. diameter, it can usually be sufficiently well localized by marking the chest with or without the aid of calipers while the patient is recumbent in the same position that he will be in during the aspiration, measuring both the puncture axis and the depth at a plane exactly 90 degrees to that axis.

The apparatus for aspiration biopsy is as follows:

1. A 20 c.c. record syringe with smooth action and good fit so that a partial vacuum can be obtained and maintained when the piston is drawn back and the mouth of the syringe is plugged.

2. One or more 18 gauge needles of 10 cm. and 15 cm. lengths; occasionally a 20 cm. needle may be required; the needles should have short bevels.

3. A sharp bistoury.

4. Six clean sterile glass slides.

5. A small curette or scraper for picking tissue particles and adherent clots from the inside of the syringe.

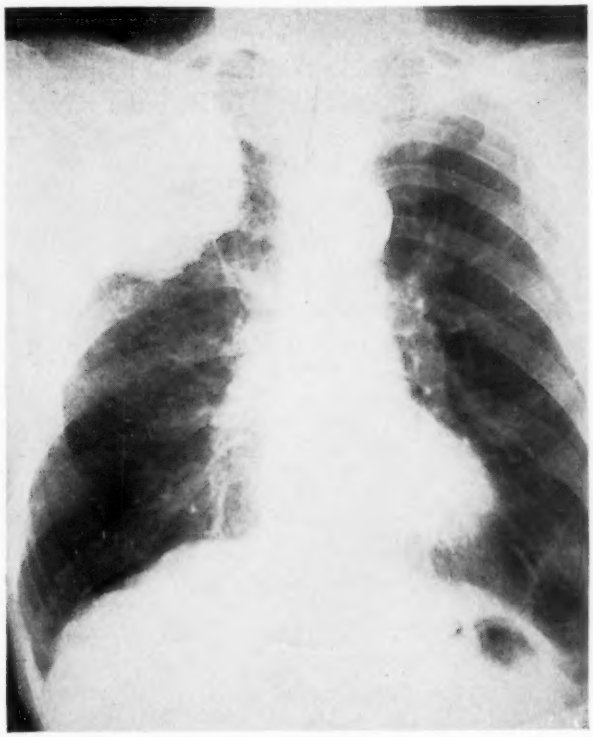

Fig. 2.—Carcinoma of lung, easily accessible by needle puncture, but with negative bronchoscopic findings (see Fig. 1).

6. A hypodermic syringe with needles about 2 inches long so that anesthesia can be carried down to intercostal tissues and pleura.

7. Small glass for holding novocain solution.

8. Sterile test tubes for fluid, blood, pus, or clot.

9. Sterile towels.

10. Sterile gloves.

Aspiration Procedure.—One-half hour before the aspiration the patient receives a hypodermic injection of $\frac{1}{6}$ gr. of morphine sulfate.

The site of election for the puncture having previously been marked with the patient in the same position as that in which he is to be

for the aspiration, and preferably marked well outside of the puncture field, so that the imaginary intersection of two lines at right angles indicates the site of the puncture, the area is shaved, if necessary, and prepared by two paintings of iodine, followed by two applications of alcohol to the central part of the area. With 1 per cent novocain, a skin wheal is raised at the site of puncture and gradually novocain is introduced through this wheal to the intercostal space and down approximately to parietal pleura. By this time the skin is thoroughly anesthetized at the wheal, and a tiny incision is made in it with the sharp bistoury, care being taken to sever the bottom elastic layers of the skin so that there will be no skin drag on the needle. The 18 gauge needle is then attached to the record syringe and slowly inserted along the predetermined axis of puncture. Usually the needle is steadily but cautiously advanced along this axis until its point is presumably at the predetermined site in the tumor. Along the way a great part of the caution consists in carefully feeling the type of resistance encountered.

Some carcinomas of the lung will be found almost leathery in resistance to the needle; others have no appreciable difference in resistance from that of normal lung tissue. If a cyst or abscess cavity is encountered, the wall may be resistant and then, as the needle slowly advances, a sudden loss of resistance will be noted as the needle enters the cavity.

There is no need for applying suction until the needle point has reached the desired spot. If the tumor is small so that fluoroscopic guidance is being used to make more certain that the needle reaches the center of the tumor, one prepares to detach the syringe in order to permit the fluoroscopic film to be brought closer to the patient, to within about 2 or 3 inches of the needle hub.

Before detaching the syringe, slight suction is applied in order to make sure that the needle point is not in a vessel or a bronchus. If blood or air is aspirated, the needle is either advanced or withdrawn a little way, until blood or air, as the case may be, no longer enters the syringe on suction. Then, the position of the needle point is checked in the vertical plane by fluoroscopy. Without a biplane fluoroscope or a horizontal x-ray tube with a portable screen the depth of the needle cannot be checked and must have been predetermined by measurements.

If the needle is not in the predetermined puncture axis and thus its point is shown to be to one side of the tumor, the needle must be withdrawn far enough so that without use of any tearing force within the lung its direction can be properly changed and it can be advanced again until it is within the tumor.

When one is satisfied that the needle is within the tumor, one hand grips the barrel of the syringe firmly, holding it absolutely steady, while

with the other hand the piston is pulled out firmly and steadily so that the strongest possible suction is applied. Maintaining this suction is one of the essentials in drawing tissue up into the bore of the needle. While this powerful suction is maintained, the syringe and needle are slowly rotated several times without any deviation from the puncture axis and at the same time the whole syringe-needle system is carefully pulled out and is thrust back in for a very short distance, not over 0.5 to 1 cm. Violent jabbing back and forth to make a pincushion of a tumor is totally unnecessary and is reprehensible. In the course of this procedure of rotating and moving the needle slightly back and forth, it will usually be found that some of the vacuum has been lost. This is discovered when the piston is slowly allowed, while constantly held, to drift back so as to release the suction, when it will be found, as a rule, that there is an air space of one to two inches beyond the piston, so that it could not be completely let down without actually pushing it down and thus forcing air into the lung. In view of the possibility of air embolism one must carefully avoid forcing any air into the lung, especially not allowing the piston to slip from one's grasp and plunge back into the syringe, an accident which would inject tumor particles and air into the lung.

Upon thus finding a partial loss of vacuum, it is recommended strongly that the syringe be detached and the piston pushed down so as to expel this air. Incidentally, if the syringe at this time contains any blood or fluid, this material should be squirted down to the bottom of a vertically held sterile test tube. In the meantime the gloved thumb of the left hand should have been quickly used to stopper the needle hub as soon as the syringe was detached so as to avoid suction of air through the needle by the patient's inspirations. The syringe, having had its piston completely pushed down again, is reattached to the needle and suction is renewed. This renewal of suction, it is believed, is important and in some cases may be repeated three or four times in order to make more certain of drawing tissue up into the bore of the needle. Then the piston is finally slowly let down to where the pressure condition with the syringe just allows the piston to come to rest, and the needle with the syringe attached is withdrawn from the patient's chest.

COLLECTION OF MATERIAL OBTAINED BY ASPIRATION

This is a part of the procedure that must be carried out meticulously. It must be borne in mind that a fragment invisible to the naked eye may be the telltale fragment under the microscope, especially in cases of punctures that are made in tough resistant tumors from which very little tissue is obtained.

Holding the point of the needle over the center of one of the slides, the stylet is passed slowly through the needle from hub towards point forcing out onto the slide any tissue lying within the needle. Adherent bits of tissue seen at the end of the stylet should be carefully teased

off and deposited on the slide. Then the syringe may be attached and air blown with a quick thrust through the needle held over the slide, as this procedure may bring down another drop or two of fluid, or tissue fragments.

If within the syringe there is seen a fragment of tissue, it may be fished out with the curette and deposited on a slide. Another clean slide is placed on top of the one on which the tissue has been deposited and with very firm pressure the two slides are squeezed together and slid along on each other for a short distance and then snapped apart. I prefer this method to drawing one slide or its end along the other, as might be done for blood smears, because it avoids dragging tissue to the ends of the slides, where it may be lost in the staining process. If the syringe, as is often the case, contains 1 or 2 c.c. of blood clot, this should all be carefully saved in a test tube, without crushing, so that it may be prepared in the laboratory for imbedding in a paraffin block and regular sectioning. Even the end of the piston should be carefully searched for tissue fragments and the bits of clot often found adhering to it.

The slides and the tube containing the clot are sent immediately to the laboratory. A report can be obtained on the slides in about ten minutes or less. Thus, if the immediate smear is positive, one may have a diagnosis within one-half hour or less from the time the puncture is begun. If the smear is negative or if its interpretation is difficult, it may be necessary to wait two or three days for the clot to be sectioned and reported. Oftentimes the clot gives very definite information, even as to histologic type. (It may be of interest in this connection to mention a case of atypically located substernal goiter, accessible to aspiration only from the posterior chest wall, in which the sectioned clot showed typical thyroid alveoli containing colloid.)

The details of the laboratory technique of fixing and staining the smears have been described by Martin and Ellis and need not be repeated here.

Caliber of the Aspirating Needle.—An 18 gauge steel needle is about as thin as one would care to risk using for deep-lung aspiration. Needles of 17 gauge are just enough thicker to give the impression of being too large and offering too much chance of trauma to vessels and bronchi. Were it possible to use a needle of even smaller bore than 18 gauge without risk of having it break, it should be possible to secure tissue almost as well. It is true that, when an aspiration biopsy done with an 18 gauge needle is positive, one usually has many times the amount of tissue that is needed. On this premise aspiration biopsies of subcutaneous tumors have been tried with ordinary 26 gauge hypodermic needles, and have been successful. Perhaps some of the newer alloys, such as are used for dentures, could be used for making needles of

less than 18 gauge that might safely be inserted in the depths of the lung without fear of breakage, and with even less danger of trauma to lung tissue.

Dangers of Needle Puncture of the Lung.—In our series of over 230 lung punctures for biopsy we have had very few troublesome sequelae. The most serious accidents were two cases believed to be examples of air embolism. In both cases, while the needle was in the patient, who was sitting up, there was sudden collapse, with tonic and clonic spasms and unconsciousness. Upon recovery of consciousness in about twenty-four hours there were various palsies which rather rapidly decreased in extent and severity so that within three weeks or thereabouts the patients were able to walk, still showing some residual motor impairment. It seemed possible, according to the neurologist, Dr. George H. Hyslop, to exclude intracranial hemorrhage and thrombosis, and he believed the evidence indicated cerebral embolism. Because of the rate and degree of improvement shown and the fact that the accidents occurred in the course of lung aspiration, it is our belief that the emboli were of air rather than solid material. We did not listen over the hearts of these patients for sounds of air bubbles nor did we examine the retinal arteries for air bubbles.

In the belief that a recumbent posture would lessen the damage of air bubbles ascending to the brain, we have done all aspirations in the past year with the patient lying flat, and during the past year no cerebral accidents have occurred.

Slight expectoration of blood may occur for twenty-four to forty-eight hours following an aspiration, but no gross hemorrhage has been encountered. The development of empyema or lung abscess has not been seen, nor has a growth of tumor along the needle tract been found in any case.

Examination of Sputum for Tumor Cells.—In two cases in a recently reported group of 175 cases of bronchiogenic carcinoma the patients happened to save gross pieces of tissue which they had expectorated. These pieces permitted sectioning in the routine manner and gave positive diagnoses. It is our routine prior to bronchoscopy to examine sputum for three successive days for tubercle bacilli and tumor cells. With the exception of the two cases just mentioned, there has been no case in which the examination of the sputum has revealed tumor cells. We have not attempted, however, to develop any special concentration or other technique for this examination. In view of the fact that these two cases yielded macroscopic pieces of positive tissue, it seems quite likely that a special effort to search the sputum day by day might yield positive diagnoses more often, and the effort seems worthy of trial, particularly for cases in which bronchoscopy, aspiration biopsy, or thoracotomy would be difficult.

SUMMARY AND CONCLUSIONS

1. Histologic proof of cancer should be a prerequisite to radical surgical or radiological treatment of cancer of the lung.

2. In a considerable proportion of cases of lung cancer bronchoscopy will not yield a positive microscopic diagnosis.

3. In the 175 cases of cancer of the lung treated at Memorial Hospital from Jan. 1, 1920, to July 1, 1939, the intravitam histologic diagnosis was made on material obtained by lung puncture in 64 cases, or 36.6 per cent; and since January, 1935, aspiration biopsy was called on to furnish the histologic material in 49 of 95 cases, or 51.6 per cent.

4. The technique of surveying a case suspected of having cancer of the lung and the technique of aspiration biopsy of the lung are given in detail.

5. The hazards of aspiration biopsy are discussed. In the Memorial Hospital series of 230 lung aspirations there has been observed no case of empyema, lung abscess, or growth of tumor along the puncture tract. Two cases believed to be examples of air embolism resulting from lung puncture have been seen. On the theory that air bubbles introduced into the pulmonary venous system and thus via the left heart into the systemic circulation tend to ascend, because of the lighter specific gravity of air as compared with blood, it is recommended that all lung punctures be done with the patient lying flat or in slight Trendelenburg position, so as to minimize the danger of air bubbles going cephalad.

6. It is advisable to use needles of the smallest caliber consistent with minimal danger of breakage, since successful aspirations can be obtained from subcutaneous tumors even with hypodermic needles if the proper technique is employed.

7. Development of techniques of searching sputum for tumor cells is worthy of trial.

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RESECTION OF THE LUNG*

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IN PAYING tribute to the memory of Edward Starr Judd by this lecture, I have selected the subject of pulmonary resection and shall present it with emphasis on the problems of operative surgery. There is no more fitting place to do this than in a lecture by a surgeon in honor of a master surgeon. Although Judd was endowed to a remarkable degree with the many other qualities that must be joined to make up the complete master surgeon, no single quality or achievement surpassed his skill and judgment in operative surgery; in this field he was pre-eminent.

Resection of a diseased organ is admittedly a crude and primitive form of therapy when compared with subtleties of modern surgery, such as removing a tiny adenoma of a parathyroid gland to prevent the recurrence of stones in the kidney or interrupting the sympathetic chain in order to preserve a limb by increasing its blood supply. The principles involved in the case of the lung are so simple and the attack so straightforward that practically the only argument lies in balancing the operative risk against the natural hazards and disabilities of the disease for which it is proposed. We may contrast lobectomy for bronchiectasis, where the question is not should it be done but can it be done, with gastrojejunostomy for duodenal ulcer where the pertinent question is not can it be done but should it be done.

Pulmonary resection is carried out as the removal of one entire lung (total pneumonectomy), the removal of one or more lobes of one lung (lobectomy, single or multiple, unilateral), the removal of lobes from both lungs (lobectomy, bilateral), the excision of a bronchovascular segment from one or more lobes (segmental pneumonectomy), or the resection *en bloc* of a portion of a lobe (partial lobectomy) or lobes (partial pneumonectomy). These operations may be one-stage, two-stage or multiple-stage procedures.

GENERAL CONSIDERATIONS

As a rule, in pulmonary surgery a two-stage procedure is carried out with the purpose of obliterating the whole or a portion of the free

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pleural space at the first operation in order to prevent or limit a subsequent pleural infection and avoid the complications of a collapse of the remaining part of the lung by a pyopneumothorax. There are other reasons, however, for dividing these operations into stages. Dense and vascular adhesions or other difficulties may make it advisable to perform a total pneumonectomy by removing the lower lobe at one operation and the remaining lobe or lobes at a subsequent date (total pneumonectomy by lobar stages). The very dense adhesions of active infection may force the operator to abandon entirely the project of immediate resection even of a single lobe and to resume the dissection at a second stage. It must be pointed out, however, that such a retreat, once the mobilization of the lung is well on its way, may be as hazardous as pushing the job to its conclusion, as the stage is set for pleural infection from divided adhesions and a pneumonic flare-up spreading from traumatized infected lung.

Ligation of the lobar division of the pulmonary artery was suggested by Sauerbruch[1] as a first-stage procedure in lobectomy. Rienhoff[2] recommends ligation of the stem branch of the pulmonary artery as well as the main bronchus as a first-stage operation in total pneumonectomy.

Cautery lobectomy or pneumonectomy (Graham) and exteriorization lobectomy (Whittemore) marked evolutionary stages in pulmonary resection and must be classified as partial or, at the best, subtotal procedures. Both operations now find a very limited sphere of usefulness or have been completely abandoned.

Removal of a lobe or lung has been accomplished by placing an elastic tourniquet around the hilum (Sauerbruch) or by the use of mass constricting ligatures (Alexander), waiting for the devitalized tissue to sequestrate or removing it at a later operation. These methods were cumbersome and invited dangers of both hemorrhage and infection. They belong to the historic aspects of pulmonary surgery.

At the present time pulmonary resection is approached in a direct manner in accordance with surgical principles established for other organs of the body. The hazards of hemorrhage, primary or secondary, have been brought under satisfactory control. The complications of infection have been lessened but still remain formidable and a source of constant apprehension. Only a beginning has been made toward insuring a balanced equilibrium of the cardiorespiratory functions during and after surgical intervention. Even the most meticulous techniques seriously encroach upon the wide margin of safety with which the body safeguards its important physiologic mechanisms, and, when this is greatly narrowed by age or grave functional disability, radical pulmonary surgery is as yet impossible.

Anesthesia.—There are certain general principles that govern both the choice of the anesthetic agent and the method of administration. Differential pressure is essential if the goal of a painstaking operation of precision with careful hemostasis is to be achieved. With present techniques adequate control of differential pressure presupposes an inhalation anesthetic, the alternative being a return to the elaborate and cumbersome methodics of the differential pressure cabinets of Sauerbruch, Robinson, and Willy Meyer. Inhalation anesthesia can be administered with control of differential pressure by using a tightly fitting face mask. Intratracheal intubation in addition to a tightly fitting mask is a more certain method and avoids inflation of the stomach.

A second important principle centers on keeping the airway clear of bronchial secretions and purulent exudate. Even though postural drainage or bronchoscopic aspiration is carried out immediately before the operation, mobilization of an infected lobe or lung expresses retained secretions into the primary bronchi and trachea. It is important to provide for the intermittent aspiration of this material during the course of the operation. Attempts have been made to blockade the infected area of lung by balloon-tipped catheters or intrabronchial tamponade, but these complicated methods will not be found necessary if efficient aspiration is carried out. This can only be done if an intratracheal tube is employed and preferably one inserted directly into the larynx rather than through the nasal route and of a cross-sectional area approximately one-half that of the trachea.

The third important principle conditions the choice of the anesthetic agent itself, as it is the rigid avoidance of anoxia during the operation and subsequently. Excluding chloroform, there are only two anesthetic agents in common use that can be administered by inhalation with sufficient concentration of oxygen to fulfill this essential requirement: cyclopropane and ether vapor. Not only because of the explosion hazard of cyclopropane but because of its apparent selective toxic effect on the heart, it has been our custom to employ ether.

At the present time, therefore, unless unusual indications are present, pulmonary resection is carried out under general inhalation anesthesia with an ether vapor oxygen mixture administered through an intratracheal tube with a closed system that permits the maintenance of differential pressure and affords ready access for aspiration of the tracheobronchial tree.

Incisions.—The merit of any surgical incision lies in affording access to the region of dissection with a minimal degree of damage to normal structures. The exposure must be adequate to permit dissection of important structures under direct vision and adaptable to any variations in pathology that may be encountered. A needlessly large

opening into the thorax is to be avoided because of the crippling of the mechanism of respiration it entails. Respiratory movements of the thoracic wall are undoubtedly a factor in promoting re-expansion of the underlying segments of lung in the postoperative period. Unnecessary damage to the latissimus dorsi and other important muscles that take part in coughing makes it increasingly difficult to maintain postoperative bronchial drainage.

Whether an anterior or posterior approach is employed, whether a rib is resected or the incision carried through an intercostal space, whether the incision is placed high or low, are details that each surgeon must settle for himself, and concerning which we may never expect unanimity of opinion. Personally, for a lower lobe lobectomy I prefer a posterior approach through the periosteal bed of the eighth rib. For a total pneumonectomy I prefer a posterolateral approach at the level of the fifth, sixth, or seventh rib, choosing a high approach if difficulty is anticipated with apical adhesions and a lower approach if basal adhesions are more likely. To gain access to the upper lobe either a posterolateral or anterolateral incision is employed. An anterolateral incision gives direct access to the middle lobe on the right or the lingula segment on the left.

Pleural Adhesions.—It is generally believed that a partial resection of one lung (lobectomy, segmental pneumonectomy, etc.) carries a lower incidence of complications and a lower mortality rate if there exists at the time of operation a complete symphysis of parietal and visceral pleura. Probably this is true if the resection is being performed for suppurative lesions in which empyema is an inevitable sequel. Obliteration of the pleural space over the surface of the lung that is to remain goes a long way toward insuring its integrity and limits the extent of the infection.

In the case of noninfected lesions in which pleural contamination is minimal or nonexistent, and in total pneumonectomy, pleural symphysis is undesirable. Pleural adhesions that are dense and vascular in themselves may add hazards to the operation that more than counterbalance the advantages of an obliterated pleural space even in suppurative disease.

On the assumption that pleural symphysis is a decided advantage, methods of artificially producing a fibrinous pleuritis have been studied in the experimental laboratory and have received clinical trial. Open thoracotomy as the first stage of lobectomy for bronchiectasis was at one time recommended by Alexander.[3] I[4] also employed it in selected cases. Pre-existing adhesions around the lobe to be resected were severed and the pulmonary ligament divided. Nonadherent areas of the parietal pleura were vigorously scrubbed with dry gauze and the chest closed. Alexander proceeded with the second stage within

approximately two weeks, while I recommended a delay of three months or longer to allow the acute reaction completely to subside.

There are several disadvantages to this method, not the least of which is twice subjecting a patient to the hazards of an anesthetic and thoracotomy. Pleural infection was occasionally encountered after the first stage. Also, not infrequently the procedure failed to produce the desired adhesions. Use of this method has almost completely been abandoned and it is recommended only if some special reason exists for anticipating difficulty in obtaining re-expansion of the remaining lobe; for example, in the case of a patient who has received prolonged artificial pneumothorax with resulting fibrosis of a nonadherent visceral pleura.

Bethune[5] devised a method of producing pleural symphysis known as "poudrage." An artificial pneumothorax is induced and talc or other mildly irritating substance is dusted on the pleural surface under guidance of the thoracoscope. Clinical reports are still too fragmentary to yield an evaluation of poudrage.

During recent years attention has been diverted from the artificial production of pleural symphysis toward active measures for encouraging early re-expansion of the remaining nonadherent lobe. The problems involved are discussed under a separate heading.

When adhesions already obliterate the pleural space, they are usually readily dealt with, but may in certain instances present a formidable barrier to surgical dissection. This is particularly true in the chronic lung abscess group with long standing and still active pneumonitis. Nevertheless, I join with Roberts and Nelson[6] in doubting "that there are any adhesions which cannot be overcome by careful dissection." Adhesions that found their origin in an episode of infection that is quiescent at the time of operation offer little difficulty. They are relatively avascular and may easily be divided by sharp dissection. Cutting under direct vision is always preferable to blunt dissection or manual separation as the fragile surface of the lung can be damaged by the use of any force. This is particularly true if compensatory emphysema is present. Transillumination of adhesions aids in the recognition of the margin of the lung and will disclose large blood vessels before they are divided.

Adhesions are best divided as close to the visceral pleura as possible. This prevents the retraction of bleeding vessels into the chest wall in what may be regions of difficult access. Bleeding from the pulmonary side of an adhesion is rarely troublesome unless the lung itself is badly torn by forceful maneuvers. Hemorrhage from the parietal side may be profuse and difficult to control. Absolute hemostasis at the end of the operation is imperative as the negative pressure re-established immediately after the incision is closed encourages postoperative

bleeding. This may be life-endangering or add to the complications of postoperative management by plugging the drainage tubes with blood clot. A massive postoperative hemothorax may require surgical evacuation.

The Interlobar Fissures.—The operation of lobectomy is not infrequently made difficult by anatomically incomplete interlobar fissures or by the obliteration of normal fissures by adhesions of inflammatory origin. The problem presented by abscesses traversing the plane of the fissures is discussed under a separate heading.

Incomplete fissures offering technical difficulty most often will be found between the dorsal segments of the lower lobes and the corresponding upper lobes. It is essential that all adjacent interlobar fissures be artificially completed to the hilum before a tourniquet is placed about the lobe. This is accomplished by the division between clamps of the pulmonary tissue in the projected plane of the fissure and the placement of hemostatic sutures. The peripheral portion of an incomplete fissure may be developed by painstaking sharp dissection, reserving the use of clamps until the vascular anastomoses that occur in the hilar region are encountered.

The fissure between the middle lobe and the right upper lobe is notorious for being incomplete or totally absent, particularly in the anterior and mediastinal region. It has been found advisable under such conditions to sacrifice a normal middle lobe with a diseased right upper lobe rather than undertake the development of this fissure. Segmental deflation as described under segmental pneumonectomy has been used to advantage to display the plane between upper and middle lobes in the completion of this fissure, the occluding clamp being placed on the middle lobe bronchus.

The development of fissures that are obliterated with inflammatory adhesions offers technical difficulties that range from the simple to the frankly impossible. If one of the lobes is normal, however, painstaking dissection will permit their separation. A normal lobe (excepting occasionally the right middle lobe) should never be sacrificed solely on the grounds of an incomplete or obliterated fissure.

Drainage.—Provision is made for drainage of the pleural cavity in every case in which a portion of a lung has been resected. In nonsuppurative cases or when contamination is minimal, an intercostal catheter is used and removed at the end of forty-eight hours. When tourniquet lobectomy has been performed, a longer drainage period will usually be advisable. I have come to this point of view only with reluctance as I am a firm believer in the general principle of the primary closure of wounds in uninfected surgical fields.

When virulent anaerobic infection is present, the need for more ample drainage is anticipated by rib resection and the placement of

a large tube. Rib resection drainage is also established primarily when pleural symphysis insures a small localized empyema cavity. To state the matter simply, the type of drainage is employed that would be indicated if the empyema already existed, but is carried out in anticipation of its actual occurrence.

After total pneumonectomy by individual ligation of vessels and suture of the bronchus, drainage is omitted if contamination has been minimal. Primary healing of the pleural cavity by the formation of a sterile fibrothorax may eliminate the necessity of a subsequent thoracoplasty. After total pneumonectomy with the tourniquet technique for suppurative lesions, drainage is provided and subsequent thoracoplasty accepted.

Just as recent developments in chemotherapy are modifying the occurrence and course of postpneumonic infections of the pleural cavity, so may the situation be changed relative to postoperative infections. Clinical tests are being made both with the local application of chemotherapeutic drugs to the pleural space and with the preoperative and postoperative establishment of an effective concentration in the blood stream.

Re-expansion of Remaining Lobe.—Following lobectomy, the concern of the immediate postoperative period centers on the re-expansion of the remaining lobe. Operative sequelae that jeopardize the integrity of the remaining lobe are varied in type and origin and it is impossible to abstract from the literature any coherent account of their nature or even of their incidence. It may also be noted that there are no data on record to indicate an increased morbidity when lobectomy is performed in the presence of a free pleural space, although this is commonly assumed to be the case.

Complications involving the remaining lobe or lobes on the operated side cannot be discussed at length, but will be briefly outlined because there is a tendency to hold too limited a view as to their origin and nature. My point of view, in general, coincides with that expressed by Edwards[19] that the lesion responsible for collapse is within the lung itself and not in the pleura.

1. *Apical Empyema:* Failure of the upper lobe to regain its integrity after a lower lobe lobectomy is commonly associated with an apical empyema. This is usually considered as the primary disturbance, but in my experience apical empyema is apt to be secondary to intrinsic disease of the underlying lung. If recognized promptly and given adequate drainage, an uncomplicated apical empyema that has become walled off from the basal area is not commonly serious or of lasting import. Postoperative collections of air or serum in the apical region should be aspirated frequently and may escape infection even though a frank empyema exists at the base. When infected, drainage in the axilla will usually be followed by re-expansion of the lobe.

2. *Atelectasis and Pneumonitis:* Atelectasis as a concomitant of postoperative pneumonitis and bronchitis may occur with or without gross obstruction to the large bronchi. Under such circumstances the failure of the lobe to re-expand is due to intrinsic factors and the apical empyema is secondary, both in origin and in importance. Drainage of the empyema under such circumstances may bring the lobe into contact with the chest wall by a shift of the mediastinum, with resulting obliteration of the pleural space but with the lobe still in a collapsed state. It is my opinion that intrinsic atelectasis and pneumonitis are commonly the first step in the complications that permanently affect the upper lobe. Minimal degrees occur not infrequently and clear spontaneously aided by breathing exercise.

In an effort to reduce this complication, further attention must be directed toward the preoperative condition of the lung. Belsey[7] has commented on the advisability of a prolonged interval between the injection of lipiodol and operation. It is our custom to demand six weeks as a minimal interval. Recent episodes of acute respiratory tract infection may pave the way for postoperative sequelae. Particularly important, however, is the existence of foci of bronchiectasis unrecognized by bronchography, or a mild degree of atrophic cylindrical bronchiectasis. Obstruction to major bronchi with resulting atelectasis may arise from inflammatory hyperplasia of hilar lymph nodes.

3. *Suppuration:* I have twice encountered frank suppuration with abscess formation in the upper lobe following lower lobe lobectomy. In both instances the lingula had been resected for extensive involvement. It is probable that this serious and formidable complication arises from operative injury to the lobe, infection centering in residual suture material or residual bronchiectatic foci. Resection of the upper lobe becomes necessary in the end.

4. *Gangrene:* Gangrene of adjacent lobe has been described as a complication of lobectomy but has not been encountered personally. While unrecognized operative injury to the vascular supply is the most likely etiology, the possibility of a retrograde thrombophlebitis is to be considered.

The volume of resected lung as measured in its preoperative state of inflation determines within general limits the readiness with which the residual space will be filled by remaining lung. Other variables, such as flexibility of the mediastinum and elevation of the diaphragm, also play their part. Little difficulty is encountered after the resection of a lobe for the atelectatic type of bronchiectasis as the remaining lobe is "accustomed" to filling the hemithorax. This contrasts with the prolonged healing that may be encountered, for example, after resecting right lower and middle lobes that are air containing and essentially of normal volume. These considerations are of importance in giving an estimate of the period of convalescence and the likelihood of complications.

There is a general impression that resection of an upper lobe presents a more difficult problem of healing than is the case with lower lobe resection. In my experience this has not been the case, as in nine patients surviving upper lobe lobectomy an apical thoracoplasty has been found necessary only in one instance (Fig. 1).

Technical measures designed to promote early expansion of the remaining lobe are under constant scrutiny. Aspiration of residual collections of air and serum has been mentioned. The placement of an anterior intercostal catheter in addition to posterior drainage may be advantageous. Postoperative bronchoscopy is indicated, particularly if there is evidence of occlusion of major bronchi. Complete reinflation

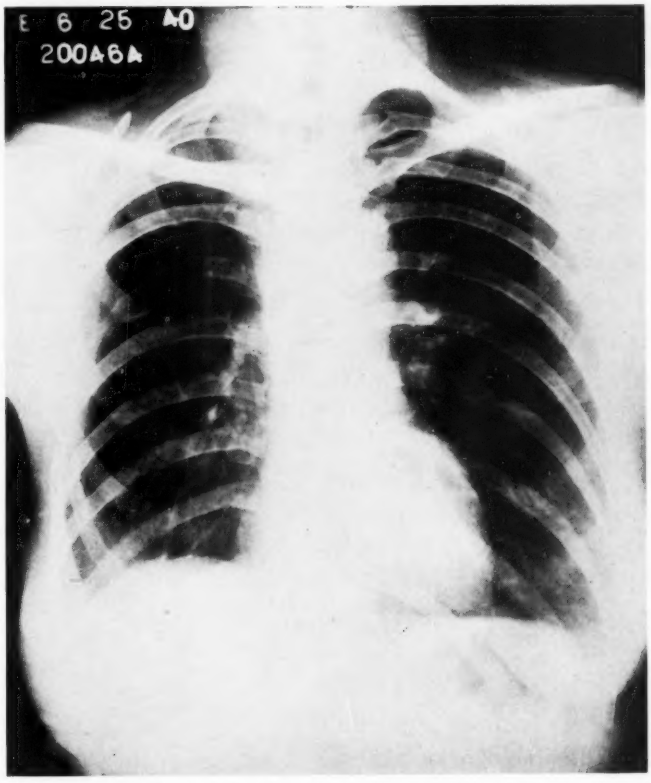

Fig. 1.—Roentgenogram taken eight months after resection of normally inflated right upper and middle lobes for bronchiectasis. Postoperative staphylococcus empyema.

of the lung by positive pressure as the chest is being closed is essential. Postoperative administration of oxygen and helium under positive pressure is recommended on theoretical grounds and is now receiving clinical assay.

Preoperative Artificial Pneumothorax.—It is assumed that there are several advantages to be derived from inducing artificial pneumothorax as a preoperative measure before total pneumonectomy for tumor. These may be listed with brief comments as follows:

1. *To Lessen the "Shock" of Opening the Pleural Cavity:* With adequate control of lung inflation by differential pressure and the avoidance of anoxia there is no disturbance of the patient's equilibrium when the chest is opened.

2. *To Stimulate a Defense Mechanism to Infection by Calling Forth a Nonspecific Inflammatory Reaction in the Pleura:* The immunologic problems involved are too complex to warrant discussion of the hypothesis constructed on this basis. One recalls the experimental and clinical evidence for and against peritoneal "vaccination."

3. *To Adjust the Organism to Maintaining Respiratory Function With One Lung:* No definitive data are available to indicate whether pneumothorax really accomplishes this result. Further clinical and experimental evidence is highly desirable.

4. *To Provide a Test of Function of the Lung That Is to Remain:* There is not available at the present time an adequate technique for determining what by analogy with the kidneys may be termed a divided or "split" test of pulmonary function. The nearest approach lies in partially reducing the functional capacity of the lung that is to be removed by an artificial pneumothorax. It is to be borne in mind that a closed pneumothorax only partially reduces the function of the lung that is collapsed.

5. *To Determine the Existence and Site of Pleural Adhesions:* Information that aids in the proper placement of the incision may be gained by pneumothorax. Usually this is obvious from studying the location of the tumor.

6. *To Aid in the X-ray Diagnosis and the Determination of Criteria of Inoperability:* Pneumothorax at times may clarify questions of chest wall or mediastinal invasion or aid in the delineation of mediastinal lymph node involvement.

7. *As a Preliminary to Thoracoscopy:* In a small number of peripherally situated tumors thoracoscopy may provide information of importance, particularly with reference to the presence of pleural seeding. Positive evidence is more important than negative, as pleural implantations may readily be overlooked. In bloody effusions aspiration with air replacement is indicated both as a palliative measure and for further diagnostic studies by x-ray and thoracoscopy if necessary.

There is no evidence at the present time that warrants the use of preoperative pneumothorax when lobectomy, in contrast to total pneumonectomy, is contemplated. A rare exception may be found in its use as a diagnostic measure. Before total pneumonectomy for suppurative lesions, pneumothorax is usually impossible and may be positively dangerous as it invites infection of the pleural space.

It may be concluded that preoperative artificial pneumothorax may be informative and possibly beneficial to the patient before total pneu-

monectomy is performed for tumor. Before lobectomy and in suppurative lesions of the lung there are few indications for its use.

Needle Aspiration Biopsy.—In the presence of bloody pleural fluid the diagnostic advantages of aspiration with or without subsequent thoracoscopy are obvious. Needle biopsy of the tumor itself to establish a microscopic diagnosis in cases that are clearly inoperable is also permissible. On theoretical grounds it is a highly questionable procedure to traverse the pleural space and normal lung tissue with a needle in order to obtain a biopsy from a tumor that may be operable. In such instances thoracotomy will usually be required to settle the question of operability and any reasonable doubt as to diagnosis may be clarified at that time.

TECHNIQUES OF PULMONARY RESECTION

Before discussing the applicability of different operative techniques in varying pathologic conditions, it is desirable to describe the several methods of pulmonary resection in some detail.

Tourniquet Lobectomy and Pneumonectomy.—While Brunn[8] deserves the credit for pointing out the advantages of a direct one-stage amputation of a lobe, the ingenious method of dealing with the pedicle originated by Shenstone has contributed enormously toward the ease and safety of the operation. The Shenstone tourniquet, or one of its various modifications, is slipped over a mobilized lobe and grasps the hilar pedicle as a snare. Distal amputation of the lobe is then carried out and the blood vessels and bronchi of the stump are secured with stitch ligatures. Release of the tourniquet then allows a neat closure of the stump by suture of the fringe of lung and visceral pleura. If normal lung tissue is available near the hilar region of the lobe, a pedicle flap outlined as the lobe is being amputated aids in a plastic reinforcement of the closure.

In the case of a total pneumonectomy the entire lung is mobilized and the tourniquet used to grasp the hilum. After amputating the lung, the stump is handled as in a lobectomy.

The advantage of the tourniquet technique lies in the ease with which the hilar stump may be closed without recourse to the crushing action of clamps or the use of mass ligatures. Suggestions that the cord of the tourniquet be left in place as a constricting ligature show a failure to grasp the real significance of the method.

The limitations and disadvantages of this form of treatment of the hilum must be kept clearly in mind. Even though constricting mass ligatures are avoided, the sutures necessary for hemostasis and bronchial closure cannot be placed with precision and of necessity result in devitalization of the contaminated tissues of the stump. Suturing this conglomerate mass of lymph nodes, large blood vessels and contaminated bronchi with chromic catgut has always been a revolting

task to the surgeon whose horizon extends to the period of tissue repair. The surprising thing is not that the method is eminently successful but that it works at all. While temporary bronchopleural fistulas almost always appear, they close as the empyema heals. The fact that secondary hemorrhage from the stump has not occurred, at least in my own experience, can only be attributed to the low head of pressure in vessels of the pulmonary circuit.

The plane of amputation with the tourniquet technique as applied to a lower lobe, passes through the origins of the terminal bronchi of the basal segment, and divides the dorsal segment bronchus distal to its first subdivision. In the case of a total pneumonectomy, the plane of amputation passes through the lobar bronchi. While in a few cases section at a higher level can be carried out by this method, individual ligation of the vessels is preferable if the stump is to be appreciably shortened. A short stump invites retraction from the tourniquet or may allow a large vessel to be turned into a bronchus so that endobronchial hemorrhage occurs when the tourniquet is released. Needless to say, control of the stump should never be entrusted to the tourniquet alone. As soon as amputation is started, clamps are used to grasp the bronchi and vessels distal to the tourniquet, and, as sutures replace the clamps, the long ends are used to steady the hilum and prevent retraction from the cord of the tourniquet.

Intrahilar Lobectomy.—If access to the hilar region is blocked by inflammatory reaction, enlarged lymph nodes, or unusually rudimentary fissures, the necessity for tourniquet amputation is conceded. When technically feasible, however, it is preferable to carry out lobectomy by individual ligation of the pulmonary vessels and amputation of the lobar bronchus as an isolated structure. The required dissection opens an unwritten chapter in surgical anatomy, and I shall briefly sketch its problems. While variations will be encountered in the anatomic pattern of the segmental divisions of the pulmonary vessels and bronchi, a general conception of the required techniques is given in the accompanying description and illustrations.

The fact that intrahilar lobectomy is more time consuming than tourniquet lobectomy must be taken into consideration before undertaking this type of operation in poor risk patients. On the other hand, a fair trial of the method gives evidence of an encouraging diminution of the suppurative complications of convalescence and a lessened incidence of temporary bronchial fistulas. Assessment of any influence on the mortality rate must await further experience.

Left Lower Lobe: The terminal divisions of the left pulmonary artery supplying the lower lobe are disclosed at the base of the fissure between lower and upper lobes. Incision of the visceral pleura at the base of the fissure discloses a large artery that supplies the basal seg-

ment (Fig. 2). As this is followed centrally, two other divisions of the pulmonary artery are disclosed that often arise at approximately the same level. One of these runs forward to supply the lingula segment of the upper lobe, and the other courses backward and downward as the artery to the dorsal segment of the lower lobe. The latter artery is usually obscured at its point of origin from the main trunk by a lymph node. Mobilization of the lymph node, particularly if it is hyperplastic, is necessary before the artery can be isolated and a ligature passed around it. Ligation of the arterial supply to the left lower lobe is therefore accomplished by securing *two* vessels, the artery to the basal segment which is readily exposed and the artery to the dorsal segment which requires further dissection. As anatomic studies of the intrahilar region are broadened and multiplied, anomalous arrangements will

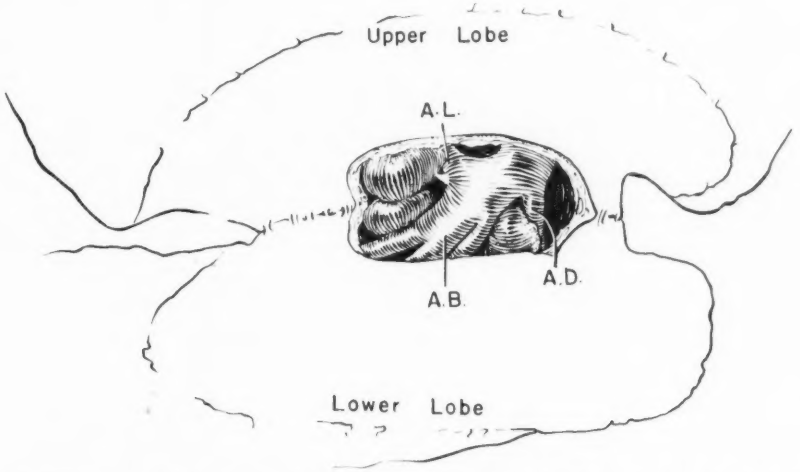

Fig. 2.—Dissection at base of fissure between upper and lower lobes of left lung. *A. L.*, Artery to lingula; *A. D.*, artery to dorsal segment of lower lobe; *A. B.*, artery to basal segments of lower lobe.

undoubtedly be recognized as commonplace. The lingula and dorsal lobe arteries have been observed, for example, to arise in a common trunk. The important safeguard in intrahilar resection of the left lower lobe is to visualize clearly the relations of these two vessels.

The inferior pulmonary vein collects the return flow of blood from the left lower lobe and conveys it to the left auricle. Its main trunk is found at the upper end of the pulmonary ligament by turning the lower lobe forward and dividing the pleura where it is reflected from the lung to the posterior mediastinum (Fig. 3). There are two major tributaries of the inferior pulmonary vein, one from the dorsal segment and the other from the basal segment of the lobe. Usually a third tributary will be disclosed joining these in the extrapericardial and extrapulmonary segments of the inferior pulmonary venous system.

Isolation and ligation of the inferior pulmonary vein as a single vessel are possible if care is taken to stay beyond the line of pericardial reflection. Ligation of the three tributaries of the vein is often preferable and is excellent insurance against damage to the pericardium.

After doubly ligating and dividing the vascular supply of the lobe, any fissures that remain incomplete may be developed and the bronchus isolated as a single structure. A Shenstone tourniquet, rather than a clamp, is employed to occlude the bronchus while it is amputated and sutured (Fig. 4). If the pathologic lesion for which the

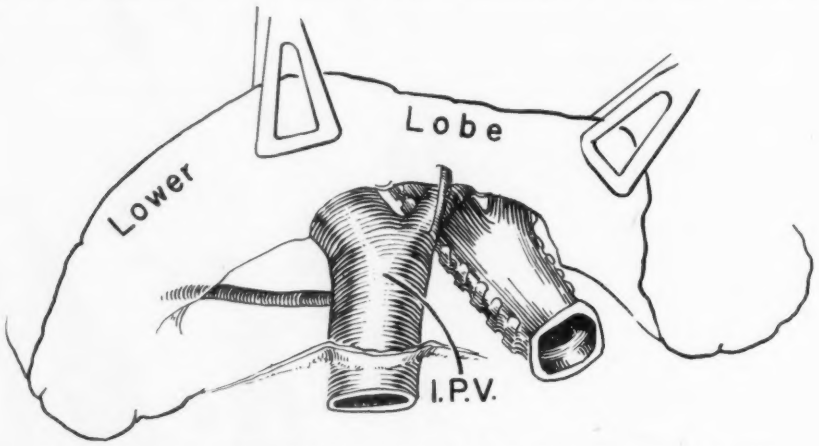

Fig. 3.—Hilar dissection left lower lobe. *I. P. V.*, Inferior pulmonary vein.

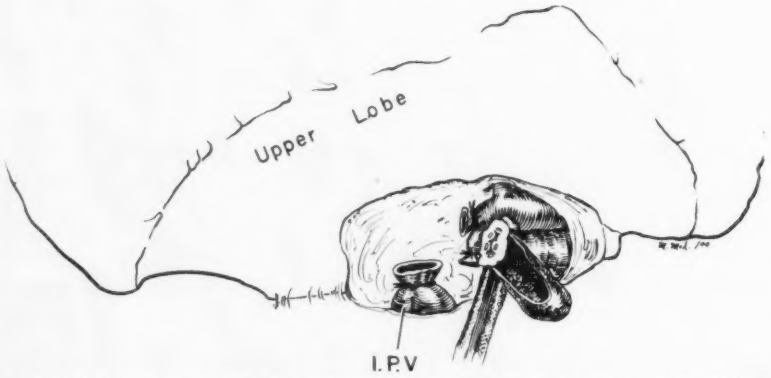

Fig. 4.—Isolated bronchus to left lower lobe grasped by tourniquet. Flap of lung for plastic closure.

resection is being performed permits, a small flap of lung tissue is left attached to the bronchus by a pedicle and used to cover the sutured end. If this is not available, adjacent mediastinal or pulmonary tissue from another lobe is utilized for this purpose. A lobar branch of the bronchial artery may be encountered in close proximity to the posterior aspect of the bronchus and require ligation.

Right Lower Lobe: Resection of the right lower lobe by this method is made somewhat more complicated by the fact that the middle lobe

bronchus arises only a few millimeters above the orifice of the bronchus to the dorsal segment. The pulmonary artery is found in the base of the fissure between upper and lower lobes by retraction of the middle

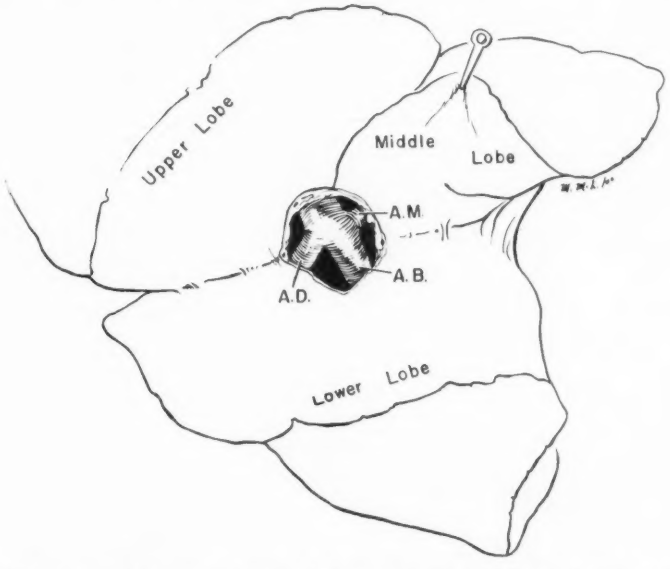

Fig. 5.—Dissection at base of fissure between upper and lower lobes of right lung. Middle lobe carried forward with hook. *A. D.*, Artery to dorsal segment of lower lobe; *A. B.*, artery to basal segments; *A. M.*, anterolateral artery to middle lobe.

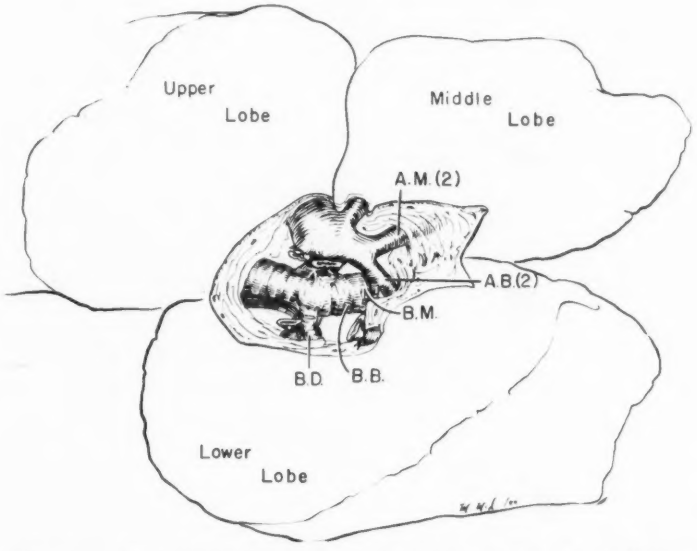

Fig. 6.—Further dissection right hilum. *A. M. (2)*, Artery to medial segment of middle lobe; *A. B. (2)*, artery to mediastinal basal segments of lower lobe; *B. M.*, middle lobe bronchus; *B. D.*, bronchus to dorsal segment; *B. B.*, bronchus to basal segments.

lobe forward and incising the visceral pleura (Fig. 5). The two large terminal divisions of the right pulmonary artery, dorsal and basal, are readily exposed, and a smaller division coursing forward to the middle

lobe can be identified. The dorsal and basal segmental arteries are divided between ligatures and as their ends retract two further divisions will be exposed that had remained concealed (Fig. 6). The more central one of these is a second artery to the middle lobe and is to be preserved. The other passes downward to supply the mediastinal basal segment and is divided between ligatures.

The inferior pulmonary vein is exposed as in a left lower lobe lobectomy and handled in a corresponding manner.

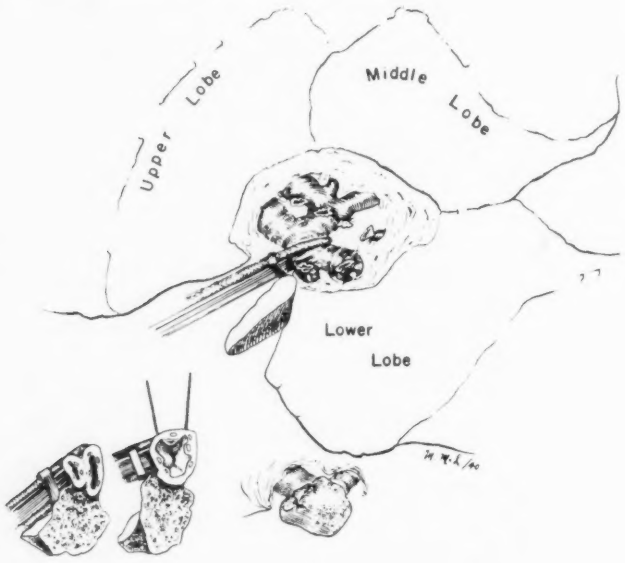

Fig. 7.—After division of arterial supply, the lower lobe bronchus is isolated and grasped with tourniquet. Flap of lung outlined with pedicle for reinforcement of bronchial closure is shown in inserts.

After completion of the fissures the bronchus is isolated and grasped with the tourniquet at the level of the origin of the dorsal segment division (Fig. 7). Care must be taken not to include the bronchus to the middle lobe which may not be seen because of its anterior position. The divided end of the bronchus in the grasp of the cord of the tourniquet will present two orifices, dorsal and basal divisions. These may be converted into one aperture by excision of the carina and then sutured. A flap of lung tissue is used for re-enforcement as described (Fig. 7, inserts).

Right Lower and Middle Lobes: Not infrequently the extent of the disease requires that the middle lobe be resected with the lower lobe. The only further anatomic consideration in such a procedure is that the venous return from the middle lobe is collected by the lowest tributary of the superior pulmonary vein and is found on the anterior aspect of the hilum by retracting the middle lobe and the lower portion of the upper lobe backward (Fig. 8).

Middle Lobe: Resection of the middle lobe alone by individual ligation technique is possible but not recommended. The bifurcation of the middle lobe bronchus occurs at a high level and the blood supply is so complicated that tourniquet technic had best be employed. The hilar stump is so small that the disadvantages of the tourniquet technique would be more theoretical than practical.

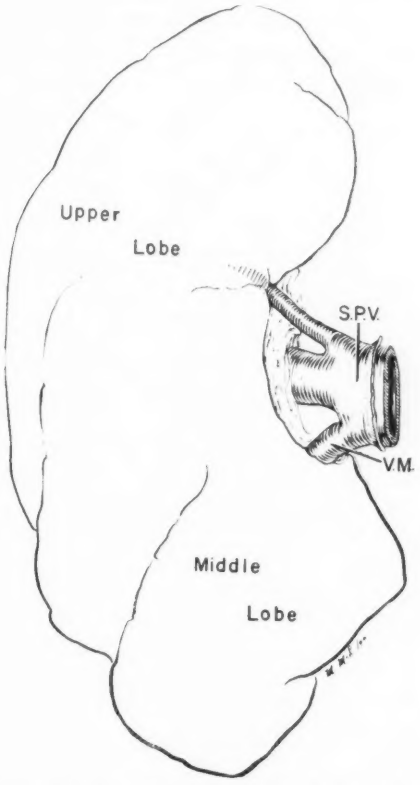

Fig. 8.—Right hilar dissection from anterior aspect. *S. P. V.*, Superior pulmonary vein; *V. M.*, tributary from middle lobe. Note line of pericardial reflection.

Upper Lobes: Time does not permit a detailed presentation of the surgical anatomy of the intrahilar regions of the upper lobes. In general, by dissecting from above downward, the branches of the pulmonary artery supplying the upper lobe are encountered in sequence and may be individually isolated and divided between ligatures. The major tributaries of the superior pulmonary veins are individually isolated and ligated as the pericardial reflection extends well over the main trunks of these vessels. If the middle lobe is to be preserved, the lowest tributary of the right superior pulmonary vein must be preserved.

Mediastinal (Total) Pneumonectomy.—The techniques of total pneumonectomy by isolation and ligation of the pulmonary vessels within the mediastinum have been so admirably described by a number of writers

(Rienhoff, Crafoord, and others) that they will not be considered in detail. In general I have followed the technique described by Rienhoff[2] for the closure of the main bronchus. A tourniquet with a round-tipped metal button attached to the end of the staff has been found useful to occlude the bronchus while the sutures are being placed. The button serves as an obturator in the flexible membranous portion of the bronchus and folds it into the rigid, cartilaginous portion. Particularly on the left where it is difficult to reapproximate the pleural edges of the mediastinal defect, it has been my custom to reinforce the closure with a free graft of tissue taken from the periphery of the excised lung.

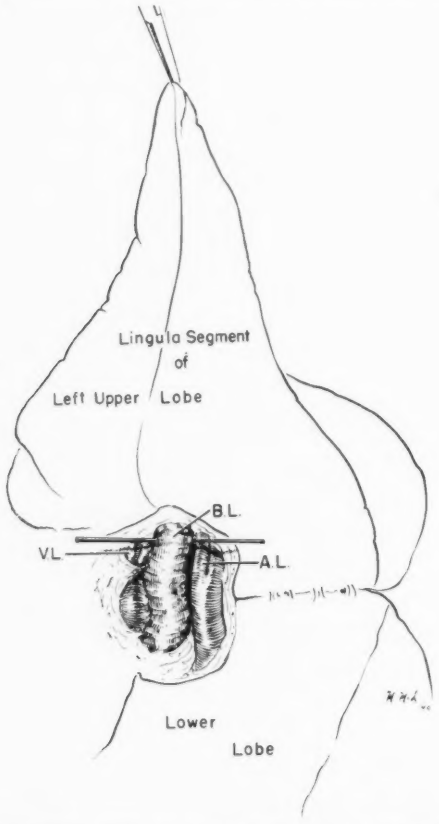

Fig. 9.—Segmental pneumonectomy as applied to lingula segment of left upper lobe. Isolation of bronchus *(B. L.)*, artery *(A. L.)*, and vein *(V. L.)*

Segmental Pneumonectomy.—The lobe became the surgical unit of the lung because of the technical convenience of the interlobar fissures. Lobectomy is in many instances a concession to operative techniques rather than a resection the extent of which is outlined by underlying pathology. Two years ago I proposed that attention be directed to the bronchovascular segments of the lung as unit structures of surgical importance.[9] The significance of these segmental divisions in diagnosis and accurate topographic localization has been discussed many times.[10, 11]

The projections of the major bronchovascular segments on the surface of the lung are easily outlined by injection of the individual branch bronchi. It was pointed out to me by Alfred Goldman that a lung macerated in a weekly corrosive solution tends to separate into these component bronchovascular segments. The artificially produced cleavage planes are not transversed by bronchi but close to the hilum anastomotic blood vessels are found with increasing frequency. The significant fact emerges that a single bronchovascular segment may be dissected from the surrounding lung if its geometric outlines can be visualized, and that the planes of this dissection are not traversed by sizable bronchi and by only a few anastomotic vascular channels.

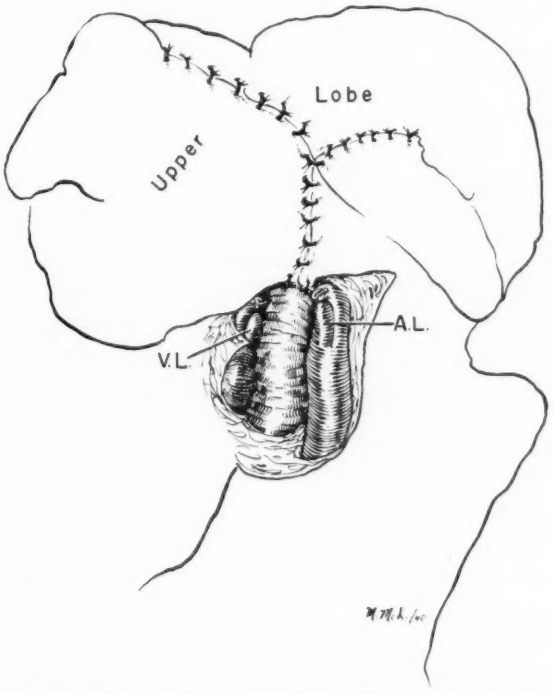

Fig. 10.—Resection of lingula completed. Bronchial stump buried and hemostatic suture line on under surface of upper lobe.

The technical problem involved becomes an exercise in solid geometry, fortunately made easy by resorting to a maneuver that may be referred to as *segmental deflation*. The bronchus and vascular supply of the desired segment are exposed by intrahilar dissection and the vessels ligated (Fig. 9). The anesthetist is then instructed to release the positive intratracheal pressure and the lung is deflated with the aid of gentle manual pressure if necessary. A light clamp or the snare of a tourniquet is then applied to occlude the bronchus. If a tourniquet is used, it is applied only to the isolated bronchus. Positive pressure is then reestablished and it will be found that the segment to be resected remains collapsed while the rest of the lung is inflated. The bronchovascular seg-

ment may then be developed by dissection in the plane between collapsed and inflated lung. Curved clamps are used on the divided lung substance to facilitate the placement of hemostatic sutures. When the isolated bronchus is reached it is divided distal to the clamp or tourniquet and secured by suture with plastic reinforcement from adjacent lung tissue (Fig. 10).

Segmental pneumonectomy finds its most common application in the resection of the lingula segment of the left upper lobe in bronchiectasis. It has also been employed to the lower lobe to excise a diseased basal segment and preserve the integrity of a normal dorsal segment. The deflation technique has also been found useful in developing the plane of incomplete interlobar fissures.

Partial Lobectomy and Pneumonectomy.—There remains for consideration the simple removal *en bloc* of a portion of a lobe or lobes, and this problem may be dismissed briefly. When the extent of the lesion or the nature of the underlying pathology does not require or permit one of the formal types of pulmonary resection that I have described, a wedge-shaped segment may be removed from the peripheral portion of the lung and the defect closed by hemostatic sutures. Particularly in suppurative lesions the high frequency cautery or actual cautery may be employed if local or regional anesthesia permits their use. If advisable, the defect may be packed with gauze and allowed to close by granulation with or without the aid of a subsequent plastic procedure. This presupposes fixation of the lung to the parietal chest wall either by pre-existing adhesions, a two-stage operation, or suture.

It will be recalled that bronchial fistulas arising from peripheral portions of the lung and fixed to the chest wall are more apt to remain open than a fistula from the hilar region that lies deeply within the thorax. This is true even though the peripheral fistula is of a much smaller caliber.

APPLICATION OF DESCRIBED TECHNIQUES

Having described the techniques of pulmonary resection, I shall briefly refer to the indications that direct their use in the diseases for which pulmonary resection is commonly employed. In referring to the series of operations on which these conclusions are based, I do not wish to imply that the methods now recommended have been consistently used throughout or, as a matter of fact, will be used for any considerable period in the future. The statistical tables are introduced to give some approximate idea of the comparative risks of pulmonary resection in different diseases and also to illustrate to a limited extent the comparative risks of lobectomy and total pneumonectomy. As stated, a comparative study of tourniquet lobectomy and intrahilar lobectomy is im-

possible at the present time. A more complete discussion of the operative results of segmental pneumonectomy will be found in a previous communication.[9]

Bronchiectasis.—Time does not permit a consideration of the general indications for pulmonary resection in bronchiectasis. This form of treatment is so well established and so generally accepted that discussion is superfluous.[12]

Tourniquet lobectomy has been the most commonly applied technique for bronchiectasis, although recently it has been found that intrahilar lobectomy can be carried out to advantage in a large percentage of cases. Segmental pneumonectomy is applied to the lingula of the upper lobe that requires resection in 80 per cent of patients undergoing left lower lobe lobectomy. If bronchograms show the disease limited to the posteromedial division of the lingula bronchus, resection of the entire lingula is not required. The middle lobe is involved and requires resection with the right lower lobe in many cases. Not infrequently the middle lobe represents the only focus of the disease, or involvement of this lobe may be combined with bronchiectasis of the left lower lobe.

Careful appraisal is advisable before a program of bilateral resection is projected. Even if the bronchi of the lobes that are to remain appear normal, alveolar structure is apt to be damaged by fibrosis and emphysema and its functional capacity reduced to a corresponding degree. In bilateral cases with scattered involvement of several bronchovascular segments, normal lung tissue may be conserved by applying the principle of segmental pneumonectomy to the lower lobes; for example, resecting diseased basal segments and preserving normal dorsal segments. There is probably no good reason at the present time for attempting to divide the lower lobe by this technique unless a bilateral program is under consideration.

Cases of bronchiectasis that require total pneumonectomy are usually so far advanced that individual ligation of the vessels will be found impossible and recourse to tourniquet technique will be necessary.

The immediate results of the application of pulmonary resection in bronchiectasis are summarized in Table I.

Lung Abscess.—The indications for pulmonary resection in lung abscess are still in a formative state and invite discussion. The necrotizing anaerobic infection of putrid lung abscess not infrequently leaves an irreparable defect in the lung. If external drainage is delayed or inadequate and the infection enters the chronic state, there will be found neighborhood foci of bronchiectasis as well as irreversible fibrotic changes. Earlier external drainage will tend to reduce the number of cases showing extensive and irreparable damage, but there will always remain instances of infection that were massive from the time of onset and certain cases that fail to receive adequate care.

TABLE I

PULMONARY RESECTIONS FOR BRONCHIECTASIS
(10-YEAR PERIOD)

	NUMBER	HOSPITAL DEATHS	%
A. Lobectomy*			
Unilateral	112	2	
Bilateral (6 cases) †	12	1	
	124	3	2.4
B. Total pneumonectomy			
Single stage	7	1	
Lobar stages	2	0	
	9	1	11.1
All resections	133	4	3.0

*Segmental resection of the lingula has not been itemized as a separate procedure when performed with or subsequent to left lower lobectomy. Two cases of segmental resection of the basal segment of left lower lobe and lingula are counted as lobectomies.

†Lt. L. + Rt. M., 3; Rt. L. + Lt. L., 2; Rt. L. + M. + Lt. L., 1.

The problem of lung abscess therapy by no means ends with the establishment of external drainage. In reported studies of end results the number of cases classified as "improved" rather than "cured" is striking. Even though subsequent healing appears sound, recurrences are not rare events. In our experience a recurrent abscess has never been cured by reestablishing drainage.[13]

Pulmonary resection may be undertaken either as a primary procedure or secondary to the establishment of external drainage. As a primary operation it is recommended for consideration in the subacute or chronic phases of the disease when multiple cavities are present or irreparable damage to the lung is apparent. Primary resection should receive consideration in upper lobe abscesses that are notoriously difficult to drain without undue mutilation of the shoulder girdle musculature or that may require subsequent thoracoplasty to bring about healing. Recurrent hemorrhage either before or after external drainage may make resection a procedure of necessity if not of choice.

In general, the reflection of a serious bout of infection on the constitution of the patient will speak for drainage as the first step in surgical treatment. As the active infection subsides, the damage may be more precisely assayed and resection employed as a measure to promote healing. I have not been at all satisfied with the use of muscle flap implantations or other form of plastic closure of residual lung abscess defects. Pedicle muscle grafts are permanently successful in my hands only if the cavity is unilocular, if it possesses flexible walls, and if there is no adjacent bronchiectasis. Under these conditions healing will usually occur spontaneously if the cavity has been adequately unroofed and drainage is maintained for a longer space of time.

In carrying out a primary resection for lung abscess, it is recommended that unusual precautions be taken to avoid emptying the abscess

contents into the bronchial tree. This may be avoided by immediate placement of a tourniquet around the hilum before mobilizing the adherent lung. If a barrier of adhesions prevents this maneuver, the outer shell of the abscess cavity may be incised and its contents evacuated by suction, accepting the added contamination of the pleural cavity that is entailed. The cavity of a large abscess will usually be entered later during the amputation of the lobe so the factor of contamination is relatively unimportant.

The edema of acute infection and the hyperplasia of bronchial lymph nodes makes intrahilar isolation of the pulmonary blood vessels impractical or actually hazardous, so tourniquet technique is recommended also for this reason. Dilatation of vessels reaching the lung from the systemic circulation, not only the bronchial arteries but small arteries from the mediastinum, makes special care in the suture of the stump imperative.

Abscesses that present on the surface of an interlobar fissure or that have crossed a fissure and extended into an adjacent lobe require special comment. A portion of the outer wall of an abscess cavity may be left adherent to an adjacent lobe if development of the fissure means damage to the normal lung. If the abscess extends into another lobe, the involved area may be excised *en bloc* or left widely opened to drain into the empyema cavity. If involvement of the adjacent lobe is extensive, total pneumonectomy may be indicated and carried out immediately or in lobar stages.

When pulmonary resection is undertaken secondary to external drainage of a lung abscess, the operation should be postponed until the manifestations of active infection have subsided. If drainage is perfect, these patients often regain a state of robust health, although they are apt to experience periodic exacerbations of infection or recurring episodes of hemoptysis or hemorrhage from a persisting bronchocutaneous fistula.

In a secondary operation mobilization of the lobe is usually readily accomplished once the zone of dense adhesions that surrounds the window in the chest wall is passed. Amputation by tourniquet technique is recommended because the fibrosis of the perivascular lymphatics within the hilum offers a barrier to dissection of the blood vessels.

The results of pulmonary resection for lung abscess tabulated in Table II show an increased hazard in operative mortality when compared to the bronchiectasis group. This increased risk is largely due to the more virulent nature of the infection harbored by these patients. Brief reference to the fatal cases illustrates this point.

CASE 1.—Primary tourniquet lobectomy for hemolytic streptococcus abscess (pure culture) of the middle lobe. Death due to generalized streptococcus bacteremia before the days of chemotherapy.

TABLE II

PULMONARY RESECTIONS FOR LUNG ABSCESS (EXCLUDING CAUTERY RESECTIONS) (10-YEAR PERIOD)

	NUMBER	HOSPITAL DEATHS	%
A. Primary lobectomy	12	2	
Total pneumonectomy			
Single stage	2	2	
Lobar stages	0	0	
	14	4	28.5
B. Secondary to drainage			
Segmental pneumonectomy	1	0	
Lobectomy	10	1	
Total pneumonectomy			
Single stage	2	0	
Lobar stages	1	0	
	14	1	7.1
All resections	28	5	18.0

CASE 2.—Primary tourniquet lobectomy for putrid post-tonsillectomy lung abscess of right upper and middle lobes. Sixteen months' duration. Death from contralateral septic pneumonia.

CASE 3.—Primary total pneumonectomy as heroic measure in a malnourished infant with diffuse necrotizing putrid infection of left lung (Fig. 11). Death on table coincident with application of tourniquet.

CASE 4.—Primary pneumonectomy in lobar stages for diffuse necrotizing and putrid post-tonsillectomy lung abscess of five months' duration. Survived right upper and middle lobe resection but infection shown to have crossed fissure to involve dorsal segment of lower lobe. Tourniquet resection lower lobe ten months later with death on table from emptying abscess cavity into tracheobronchial tree during mobilization of lobe.

CASE 5.—Tourniquet lobectomy right upper lobe following three drainage operations for multilocular putrid abscess, bronchiectasis, and diffuse pneumonitis of three years' duration. Death from septic bronchopneumonia and empyema.

Cystic Disease.—Both the clinical and pathologic definition of congenital cystic disease of the lung are difficult, and only a few cases have been grouped under this heading. Doubtlessly others have been included under lung abscess or bronchiectasis. The principles that govern pulmonary resections for abscess and bronchiectasis are applicable to cystic disease and need not be repeated. As one death occurred from contralateral pneumothorax occasioned by the perforation of a subpleural cyst of the supposedly sound lung, this consideration should be kept in mind.

Table III probably gives too grave an estimate of the hazards of pulmonary resection in this disorder. The number of cases is too small for appraisal on a percentage basis.

Tuberculosis.—The efficacy of collapse therapy at a relatively low risk has kept pulmonary resection for tuberculosis at a minimum. Advance has been made more through operations performed under mistaken diagnoses than by deliberately planned resections.

Fig. 11.—Patient described in Case 3.

At the present time bronchial stenosis is the most suggestive indication for resection in this disease and presents the greatest obstacles for treatment by any other measure. Blocked cavities, either air containing or filled with caseous material that has not found an outlet into the bronchial tree, may offer indications for resection. A third possible indication for extirpation may exist in lesions so situated that the likelihood of closure by collapse therapy is slight. The enthusiast should

tread on this ground with caution and only after a long experience with modern methods of collapse therapy.

TABLE III

PULMONARY RESECTION FOR CYSTIC DISEASE
(10-YEAR PERIOD)

	NUMBER	HOSPITAL DEATHS	%
Lobectomy	3	0	
Segmental pneumonectomy	1	0	
Total pneumonectomy			
Single stage	1	1	
Lobar stages	1	1	
	6	2	
All resections	6	2	33.3

On theoretic grounds clinical experiments with pulmonary resection in tuberculosis should be limited to cases of chronic isolated bronchogenic phthisis.[14]

Resection should be carried out by individual ligation of vessels and suture of the bronchus unless access to the hilar region is absolutely blocked. A limited experience indicates that hilar dissection in tuberculosis is more readily accomplished than in bronchiectasis, due to less inflammatory reaction in the peribronchial lymphatics. Once the primary lesion is established, tuberculous foci in an organ do not produce a lesion in the corresponding lymph nodes.[14] It may also be pointed out that pre-existing pleural effusion attending artificial pneumothorax therapy may result in an almost bloodless cleavage plane as contrasted with areas in which a diseased lung has remained in contact with the parietal chest wall. A preceding pleural effusion, therefore, is in no way a contraindication and may indeed provide strategically favorable conditions.

A limited experience with pulmonary resection in tuberculosis is recorded in Table IV.

TABLE IV

PULMONARY RESECTION FOR TUBERCULOSIS
(10-YEAR PERIOD)

	NUMBER	HOSPITAL DEATHS	%
Lobectomy	2	0	
Total pneumonectomy			
Single stage	2	1	
Lobar stages	1*	0	
	5	1	
All resections	5	1	25

*Preoperative diagnosis of bronchiectasis.

Tumors.—The challenge of neoplastic disease has been second only to the exigencies of wounds of battle in leading surgeons to overstep the limitations of established precedent. Tumors are classified as benign or malignant on the basis of the natural history of their behavior rather than on the basis of whether or not they may prove fatal to the individual patient. It is important to bear this fact in mind in any consideration of pulmonary neoplasms, as a small benign tumor not infrequently produces the fatal sequelae of bronchial obstruction. A classification based on the natural history of the tumor is, however, of great importance in determining the type and magnitude of surgical resection.

During the ten-year period ending April 1, 1940, a clinical diagnosis of primary tumor of the lung was made in 380 cases at the Massachusetts General Hospital.[15] It was confirmed by microscopic examination in 172 cases, of which 155 are classified as primary bronchogenic carcinoma, 15 as adenomas or carcinoids, 1 as neurofibroma, and 1 as hamartoma. The frequency of benign tumors in the entire group is but 4.4 per cent, a relatively insignificant number. The frequency calculated for the group with microscopic confirmation of the diagnosis rises to 10 per cent. If attention is directed to the group in which resection was carried out, it is found that benign lesions account for approximately 30 per cent of resectable bronchogenic tumors. If consideration is still further limited to patients surviving resection with apparent arrest of the disease, benign lesions comprise 64 per cent. These figures are cited to show how important it is for surgeons and pathologists to agree in their definitions before comparing results in the treatment of pulmonary neoplasms.

Bronchial Adenoma (Carcinoid): It is said that this tumor can be adequately handled by bronchoscopic methods, either by extirpation with or without the use of the diathermic electrode, or by the application of radium. In only 4 of 15 cases has this approach been applicable clinically or given satisfactory clinical results. A careful study of the gross lesion in the 11 cases subjected to resection gives convincing evidence of the inadequacy or frank impossibility of eradicating the tumor by endoscopic methods. The extraluminal portion of the tumor is almost invariably of much greater bulk than the intraluminal portion. In addition, the lung distal to the obstructing tumor has suffered irreparable damage.

In our experience lymph node involvement has not been observed as an early or late manifestation of bronchial adenoma. Resection of the tumor itself, therefore, with the segment of lung that has been irreparably damaged appears to be an adequate therapeutic goal. As the tumor rarely is situated distal to the lobar bronchi, lobectomy will be the minimal extent of the resection. In early cases with a minimal degree of infection and lung damage intrahilar lobectomy is advisable as the bronchus must be amputated at a high level. If the tumor impinges

upon the orifices of other lobar bronchi, as is often the case, total pneumonectomy is required. In long-standing infection with a barricade of hilar fibrosis tourniquet amputation of the lung may be required, even at the cost of leaving the tumor in situ for later resection if symptoms require it.

Other benign tumors are rarities that may be handled by as conservative methods as their size and location permit (Table V).

TABLE V

PULMONARY RESECTION FOR BENIGN TUMORS
(10-YEAR PERIOD)

	NUMBER	HOSPITAL DEATHS	%
Carcinoid (''adenoma'')			
Lobectomy	5	1	
Total pneumonectomy			
Single stage	3	0	
Lobar stages	1	1	
	9	2	22.2
Hamartoma			
Partial lobectomy	1	0	
Neurofibroma			
Lobectomy	1	0	
	2	0	
All resections	11	2	18.1

Bronchogenic Carcinoma: Of 156 primary malignant tumors of the lung confirmed microscopically, 155 have been carcinomas and 1 has been sarcoma. The single case of sarcoma was treated by total pneumonectomy and is well. Of the 155 cases of primary carcinoma, operation appeared feasible in 52 (33.6 per cent). Twenty-five cases were proved inoperable by thoracotomy and resection was carried out in 27 (17.4 per cent). Fifteen of the 27 subjected to resection died in the hospital and 7 have died subsequently of their disease. There are now living 5 patients with no apparent residual or recurrent disease (Table VI).

These results are very similar to those reported by Edwards,[16] who notes a salvage of 6 patients out of a total of 172 cases. They are not far different from the situation that is found in carcinoma of the stomach where a salvage of 10 five-year cures out of a total of 200 cases is a representative result.[17]

In a consideration of the type of resection that is to be carried out for primary carcinoma of the lung, the problem of the removal of regional lymph nodes comes immediately to attention. The ideal operation for cancer in other organs has been established as the total resection of the organ and the removal *en bloc* of regional lymphatics. An exception, im-

portant by analogy, may be noted in the case of the stomach, as total gastrectomy is commonly performed only when the site of the primary growth demands sacrifice of the cardia.

In proposing total pneumonectomy as the only acceptable procedure for carcinoma of the lung one must take into consideration the differential operative mortality rate of the complete operation as contrasted with that of lobectomy. It will also be recalled that the possibility of a lasting arrest of malignant disease diminishes to a discouraging degree once involvement of the lymph nodes has occurred, so relatively few patients may be saved by even the most radical procedures. The lymphatic system of the hilar region is exceedingly complex and poorly designed for precise surgical dissection.

When total pneumonectomy is proposed in order to remove more adequately a potentially invaded lymphatic area, the question may be framed in simple terms: What price is paid in operative mortality for a few additional centimeters of regional lymphatics? In the greater number of cases of bronchogenic carcinoma this question will not be raised because either the anatomic site of the primary tumor in the hilar bronchi will demand total pneumonectomy, or gross invasion of hilar nodes will call for an attempt to remove them. I refer only to a limited group of cases with peripheral tumors and without gross involvement of regional lymphatics. In these instances I continue to advise lobectomy.

Lobectomy and total pneumonectomy for carcinoma should be carried out by intrahilar and mediastinal dissection technique. Recourse to tourniquet amputation is to be condemned except under unusual circumstances.

TABLE VI

PULMONARY RESECTIONS FOR MALIGNANT TUMORS
(10-YEAR PERIOD)

	NUMBER	HOSPITAL DEATHS	%
A. Primary			
Sarcoma			
Total pneumonectomy	1	0	
Carcinoma			
Lobectomy	7	2	
Total pneumonectomy	21	14	
	29	16	55.0
B. Metastatic			
Partial lobectomy			
Unilateral	1	0	
Bilateral (1 case)	2	0	
Lobectomy	2	0	
Total pneumonectomy	1	0	
	6	0	0
All resections	35	16	45.7

Metastatic Tumors: The status of pulmonary resection for known metastatic tumors of the lung is admittedly one of experimentation. In general, it may be taken under consideration when a solitary metastasis of a tumor of relatively low grade malignancy appears in the lung after complete eradication of the primary growth. It is also to be considered in cases of hypernephroma with a solitary pulmonary metastasis.[18]

Resection of metastatic tumors is usually a simple matter technically as the complications of infection that are found in primary tumors are absent. Peripheral nodules may be removed *en bloc* and larger growths resected by lobectomy or pneumonectomy with intrahilar or mediastinal dissection. Metastases to the bronchial wall may closely simulate primary bronchogenic carcinoma as the signs and symptoms of bronchial encroachment result.

TABLE VII

ALL PULMONARY RESECTIONS
(10-YEAR PERIOD)

	NUMBER	HOSPITAL DEATHS	%
Bronchiectasis	133	4	3.0
Lung abscess	28	5	18.0
Cystic disease	6	2	33.3
Tuberculosis	5	1	25.0
Benign tumors	11	2	18.1
Malignant tumors	35	16	45.7
	218	30	13.8

TABLE VIII

ALL PULMONARY RESECTIONS
(10-YEAR PERIOD)

	NUMBER	HOSPITAL DEATHS	%
Lobectomy			
Partial	6	0	
Complete	166	9	
	172	9	5.2
Pneumonectomy			
Single stage	40	19	
Lobar stages	6	2	
	46	21	45.6
All resections	218	30	13.8

CONCLUSION

Tables VII and VIII summarize the experience of the past ten years with various types of pulmonary resection performed for diseases that commonly present indications for surgical therapy.

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SURGICAL CONSIDERATIONS OF PRIMARY CARCINOMA OF THE LUNG

Review of the Literature and Report of 19 Cases

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THE thoroughly deserved increasing attention and relatively recent revival of interest in primary carcinoma of the lung are probably due to several factors. Of these the most important are the apparently increasing incidence, the relative frequency, the rapid advances in thoracic surgery, and the demonstrated feasibility of surgical therapy. The relatively high incidence of carcinoma of the lung has been insufficiently realized. At present, according to a number of statistical studies,[23, 37, 86, 88] the lung ranks second in frequency only to the stomach as the primary site of cancer. At Charity Hospital in New Orleans among the necroscopies performed during the past year carcinoma of the lung occurred more frequently than carcinoma of the stomach.[39] Yet, only three decades ago, Adler,[4] who reviewed the literature on the subject, stated: "On one point, however, there is nearly complete consensus of opinion and that is that primary neoplasms of the lung are among the rarest forms of the disease." Whether this phenomenal rise in incidence is due to an apparent or a real increased frequency is still controversial. In a previous publication[117] an extensive review of this phase of the subject was presented and on this basis we are of the opinion that the increase is actual and not only apparent. Of even greater practical significance is the factor of therapy. In the short span of approximately a decade the prognosis in this condition has been reversed from absolutely hopeless to relatively favorable. There are records now of a number of patients living and well five years or more after operation. This has been due chiefly to the rapid strides that have been made in the technical development of thoracic surgery. In fact, these developments have evolved now to such a perfected state that the most important consideration lies in the establishment of early diagnosis.

Whereas in the past there has been some controversy among surgeons and radiologists concerning the relative therapeutic values of operative removal and irradiation in malignancies, at present it is the general consensus that the only curative treatment of primary carcinoma of the lung is surgical extirpation. In inoperable and absolutely hopeless cases irradiation therapy may be of value as a

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palliative procedure in the alleviation of manifestations.[163] It has also been claimed that life may be prolonged a few months. King[87] found that the average duration of life in those cases treated by irradiation was 15.4 months as compared with 9.3 months for the entire series. In 59 cases treated by irradiation, Chandler and Potter[29] found that the average duration of life was 11 months; whereas, in 61 untreated cases it was 6 months. Similarly, Ormerod[118] also observed a slight increase in duration of life of the treated series. The only case reported that has lived 5 years following irradiation therapy is that of Harper.[67] On the other hand, Brock,[26] who is of the opinion that irradiation therapy is of little value in prolonging life, refers to a case in which the patient lived 8 years after onset of symptoms without any treatment. In fact, there is some evidence that irradiation therapy actually may be detrimental.[25, 104, 127] Overholt[127] found that the average duration of life in a series of cases treated by irradiation was 5.6 months; whereas, the untreated cases lived 8 months. Saupe[145] observed that 50 per cent of the patients in a series of 200 cases treated by irradiation died in the first 3 months after treatment and only 15 per cent showed any improvement. We agree with numerous other investigators[164] that irradiation therapy in primary carcinoma of the lung is of little, if any, value.

Whereas it is now generally agreed that surgical treatment is the only form of curative therapy, apparently some[41, 95, 111, 155] are not yet convinced that total removal of the involved lung is the procedure of choice. These believe that lobectomy is indicated in selected cases. As previously emphasized, it is our firm conviction that any procedure short of total removal of the involved lung is irrational and only by total pneumonectomy can the primary focus as well as the regional lymph nodes be adequately removed. Obviously lobectomy does not permit extirpation of the regional lymph nodes and the significance of this fact is clearly emphasized by the high incidence of lymph node involvement. In a series of 2,579 collected cases the regional lymph nodes were involved in 75.9 per cent. That this is not a theoretical argument is shown by the fact that in Forni's[56] collected cases of pneumonectomy the incidence of recurrence was 9 per cent in contrast to 25.8 per cent following lobectomy.

Operability.—The operability in carcinoma of the lung is dependent upon a number of factors. Everything else being equal, the operability, as in carcinoma elsewhere, depends upon the length of time which has elapsed since the onset of symptoms. Many of the cases which have been allowed to progress for a considerable period of time are inoperable when they are first seen by the physician. Factors which preclude the possibility of resection are distant metastases; involvement of the contralateral lung; evidence of advanced mediastinal involvement, as indicated

by marked widening of the mediastinal shadow in roentgenograms; fixation of the trachea and bronchi and widening of the carina as well as extension of the neoplastic process above the bifurcation, as determined bronchoscopically; involvement of either the phrenic or vagus nerves, as indicated by paralysis of the diaphragm and vocal cords respectively; and extension of the neoplastic process to the pleura, demonstrated by thoracoscopic examination and by the presence of malignant cells in the aspirated pleural fluid. In addition to the manifestations of involvement by the malignant process itself, debility and advanced age are contraindications to radical extirpation.

Whereas most of the factors mentioned above are evidences of inoperability, widening of the carina and apparent fixation of the trachea and bronchi in themselves are not justification for omitting exploration, because occasionally one is agreeably surprised to find that the apparent mediastinal involvement is on an inflammatory basis and that extirpation of the involved lung together with the inflammatory mediastinal nodes is possible. On the other hand, apparently operable cases occasionally will be found inoperable at exploration because of involvement of important mediastinal structures by the neoplastic process or because of the impossibility of completely removing the tumor. *It is our firm conviction, however, that borderline cases should always be given the benefit of exploration even at the risk of closing up a relatively large number without removing the tumor, because it is the only means by which operability can be absolutely determined in these instances.* The operability in carcinoma of the lung is still far too low, probably due to the fact that the diagnosis is not made early. In 139 collected cases[9, 26, 48, 127, 133] 68 (49 per cent) were operable; whereas, in our series of 30 cases 19 (63.3 per cent) were operable. Our higher operability incidence is probably due to the fact that we have explored cases which apparently were inoperable, but in which we found at the time of operation that a satisfactory extirpation of the involved lung and regional lymph nodes could be done.

As previously emphasized, we are convinced that a preliminary artificial pneumothorax is extremely desirable in the preparation of these patients for pneumonectomy. Generally one to two weeks are required to complete the pneumothorax, which is done in stages, increasing the amount of intrapleural pressure gradually until the pressure is definitely on the positive side. Preoperative pneumothorax is of diagnostic importance in determining the presence, extent, and location of adhesions, thus permitting the preoperative planning of the operative procedure. It is desirable also following pneumothorax to take roentgenograms with the patient in the head-down position in order to determine more clearly the extent of adhesions between the base of the lung and diaphragm. In cases in which there are extensive basal adhesions, a posterolateral approach is preferable; and in cases in which there are apical adhesions, the

best operative approach is an anterior one. Another decided advantage of preoperative pneumothorax is the gradual compression of the pulmonary capillary bed which gives the right heart a chance to compensate for the increased peripheral resistance in this area, thus mitigating the sudden change which occurs following the cutting off of the blood supply to the involved lung at the time of ligation of the pulmonary vessels. This is particularly true in elderly patients whose cardiac reserve is diminished and in whom malignancy of the lung is likely to occur. Edwards[48] has emphasized that an additional advantage of the preliminary artificial pneumothorax is that it permits the determination of the ability of the patient to carry out respiratory function with one lung by compressing the normal remaining parts of the affected lung. He also believes that the opening of the pleural cavity at the time of operation is accomplished with less discomfort to the patient if a preliminary artificial pneumothorax has been done. We have not used the intrapleural injection of beef broth as suggested by Rienhoff,[134] which presumably increases the reaction of the pleura and prevents infection. Recently this procedure has been successfully used by Samson and Holman.[142]

Another preparatory measure consists in the general rehabilitation of the patient. It is important to place the patient on a high vitamin, high caloric diet. Because of the frequency of an associated infection and consequent vitamin C deficiency, it is essential that these patients be given large doses of cevitamic acid. Generally we administer at least 500 mg. daily for a week or ten days prior to the operation. In addition to this they are given thiamin chloride in approximately 30 mg. doses daily for the same period of time. This latter increases the appetite and gets them in better physical condition. As patients with pulmonary carcinoma usually have an anemia because of the associated infection and hemorrhage, transfusion of whole blood should be given preoperatively. At the time of operation it is necessary to have two or three available donors, because prolonged bleeding may follow division of extensive adhesions and because of the possible accidental massive hemorrhage in which administration of blood during operation is frequently lifesaving.

The problem of anesthesia in intrathoracic surgery is a most important consideration. No attempt will be made here to discuss in detail this phase of the subject as this has been adequately reviewed in previous publications.[13, 14, 51, 71, 76, 98] Suffice it to say that the most important desiderata are complete control of intrapulmonic pressure, adequate facilities for aspiration of secretions in the respiratory passages during the operation, the maintenance of quiet respirations and high oxygenation, the avoidance of distressing cough reflex, and the rapid return to consciousness following completion of the operation. It is

obvious, therefore, that the availability of a skillful and highly trained anesthetist is essential. Probably in no other operative procedure is this a more important consideration. Moreover, a highly trained anesthetist can greatly facilitate the technical difficulties of the operation by "'washing out'' the carbon dioxide and thus keeping the patient in relative apnea. Because the operative procedure of pneumonectomy entails the wide opening of the thoracic cage, pulmonary ventilation may be embarrassed. For this reason readily available positive pressure is desirable. This is considerably facilitated by the presence of an intratracheal tube. Moreover, aspiration of secretions in the tracheobronchial tree is more easily performed with an intratracheal tube in place. Whereas in a previous publication we stated that there were certain undesirable features associated with the use of an intratracheal tube, we are now of the opinion that these disadvantages may be obviated by greater care and skill in its introduction. Of particular importance also is the preoperative bronchoscopic aspiration of any secretions in the tracheobronchial tree. This will minimize considerably the spillage of retained secretions in the involved lung during the course of the operation. Bronchoscopic aspiration should also be done immediately following the completion of the operation. This procedure will decrease considerably the incidence of postoperative pulmonary complications.

Whereas the choice of anesthetic agent appears to be a matter of personal preference, there is unanimity of opinion regarding the fact that it should be one which permits the administration of a high concentration of oxygen. This is possible with both cyclopropane and ether. On the basis of our experience the former is preferable. On the other hand, Beecher[14] is convinced that ether is better.

Whereas the majority of thoracic surgeons have employed general anesthesia for intrathoracic procedures, more recently others[27, 93, 99, 148] have indicated their preference for local and spinal analgesia. Although we have had no experience with these forms in intrathoracic surgery, we are in complete accord with Beecher[13, 14] and Blades[20] that their dangers and disadvantages do not justify their routine employment.

There are several types of incisions which may be employed and their choice depends to a great extent upon the presence or absence of adhesions. In cases in which there are no adhesions, the anterior approaches, as suggested by Rienhoff[133, 134] and Overholt,[122] are preferable because they permit excellent exposure and are less extensive. The Overholt incision is particularly indicated in cases in which there are extensive adhesions between the upper lobe and the parietal pleura. On the other hand, in cases in which there are extensive adhesions between the lower lobe and the posterior parietal pleura or diaphragm,

a better exposure will be obtained by means of a posterolateral approach, because in this way the adhesions can be divided under direct vision by sharp dissection, which is much less traumatizing and will result in less oozing. Moreover, as suggested by Edwards,[48] a posterior incision is more expedient in cases with involvement of the lower lobe and an anterior incision is of greater value in cases with involvement of the upper lobe. The anterior approach, as popularized by Rienhoff, consists of a transverse incision over the third intercostal space extending from the lateral border of the sternum to the anterior axillary line. The pectoral muscles are divided and the pleural cavity entered through the third intercostal space. Greater exposure is gained by separating the third and fourth ribs after disarticulating their costochondral junctions. We previously modified this incision by resecting the third rib instead of making an incision in the intercostal space, but have abandoned this because of the difficulty in closing the thoracic wall. Because of the occasional difficulty in getting adequate exposure through the simple incision in the third intercostal space, we consider it desirable to divide the third and fourth costal cartilages in the parasternal portion; if the lesion is high in the upper lobe with extensive adhesions between the visceral and parietal pleurae, division of the second costal cartilage gives adequate exposure (Figs. 1 and 2). It is imperative that the internal mammary vessels should be ligated above and below because considerable hemorrhage can occur from these vessels if they are injured (Fig. 2). Through this incision with division of the costal cartilages, adequate exposure to the hilum of the lung can be obtained and closure of the thoracic cage is greatly facilitated. Another anterior approach which has been quite popular is that suggested by Overholt[122] and Edwards.[47] According to the former a curved incision is made extending from about the fifth sternochondral junction below to the anterior axillary line near the clavicle and the breast mobilized upward and medially as a flap. The pectoral muscles are divided in the second interspace through which the pleura is entered and the cartilages of the first to the fifth ribs divided parasternally. The approach employed by Edwards consists of a right-angled incision, beginning parasternally in the region of the second intercostal space, extending caudally to the fifth intercostal space and then laterally in the fifth intercostal space to the axilla. The third, fourth, and fifth costal cartilages are divided and the intercostal structures in the fifth intercostal space are incised. There are two posterior approaches which can be used. The posterolateral begins in the fifth intercostal space in its paravertebral portion and extends anteriorly to the anterior axillary line. This incision is made through the fifth intercostal structures into the pleural cavity (Fig. 3). The paravertebral portions of the fifth and sixth ribs are divided, permitting

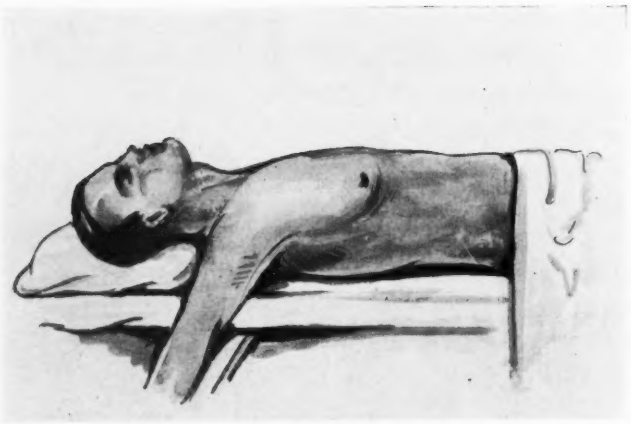


Fig. 1.—Drawing showing position of patient in anterior approach for pneumonectomy. The patient lies in the dorsal position with the arm of the affected side abducted.

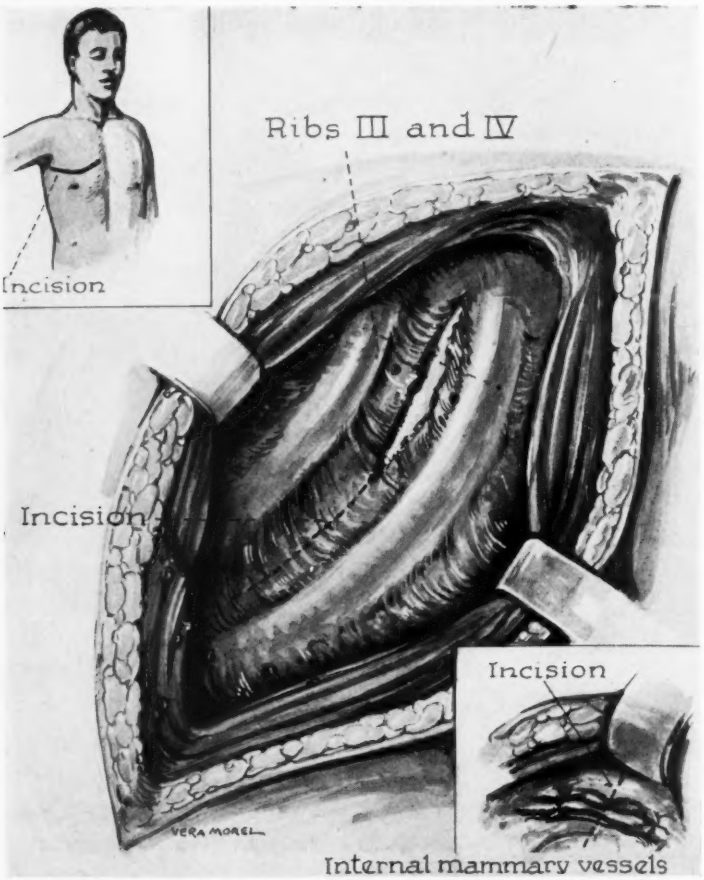


Fig. 2.—Drawing illustrating anterior approach for pneumonectomy. The incision is made transversely over the third intercostal space extending from the lateral border of the sternum to the anterior axillary line. The pectoral muscles are divided and the pleural cavity entered through the third intercostal space. A plexus of veins is frequently observed in the lateral aspect of the incision immediately beneath the pectoral muscles and over the ribs and intercostal muscles. Annoying hemorrhage from the veins will occur unless preliminary ligation is done. Lower inset shows method of section of the mammary vessels between transfixion ligatures.

wider separation. This incision is particularly indicated in cases with lower lobe involvement and with extensive adhesions in this area. A popular incision is that suggested by Crafoord.[35] It has the distinct advantage that a wide exposure of the hemithorax is given, but it has the disadvantage that it is an extensive incision and produces considerable trauma. It begins posteriorly in the paravertebral portion of the fourth rib, about 7 to 8 cm. from the posterior midline, extends downward beneath the angle of the scapula, and then up toward the midaxillary line to the level of the fifth rib which is followed anteriorly to the costal cartilage. After mobilization of the scapula, the fifth rib is resected throughout the entire length of the incision and the pleural cavity entered through its bed.

Fig. 3.—Drawing illustrating position of patient in posterolateral approach for pneumonectomy. The incision is made over the fifth intercostal space extending from the paravertebral line to the anterior axillary line.

Following the opening of the pleural cavity and the division of the adhesions by sharp dissection, the hilar structures are exposed in the mediastinum. The hilum is exposed in the mediastinum by incising the mediastinal pleura anteriorly and superiorly in the anterior approach and posteriorly and superiorly in the posterior approach. In the anterior approach care is taken not to injure the phrenic nerve or the accompanying pericardophrenic vessels. The incision is generally made posterior to these structures. Crushing of the phrenic nerve by means of an artery forceps is desirable as it facilitates the operative procedure by producing a hemidiaphragmatic paralysis and is also of value in the early postoperative period by helping obliterate the hemithorax. A flap of mediastinal pleura which is mobilized by the respective incisions is reflected, exposing the hilar structures. The mobilization is greatly facilitated by the use of long, ball-tipped, slightly curved scissors (Fig. 4).

Following mobilization of the mediastinal pleural flaps over the hilum of the lung, the hilar structures are isolated individually. In previous publications great emphasis was placed on this procedure.

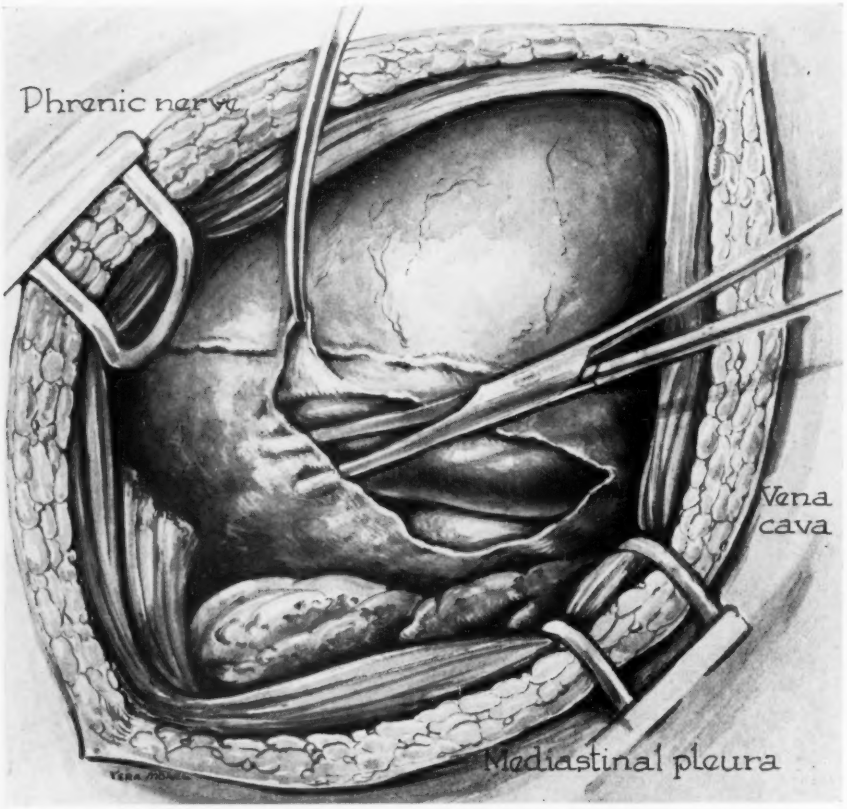


Fig. 4.—Drawing showing exposure of hilar structures in anterior approach for pneumonectomy. The mediastinal pleura is incised anteriorly and superiorly posterior to the phrenic nerve. Mobilization of flaps of mediastinal pleura is greatly facilitated by the use of long, ball-tipped, slightly curved scissors.

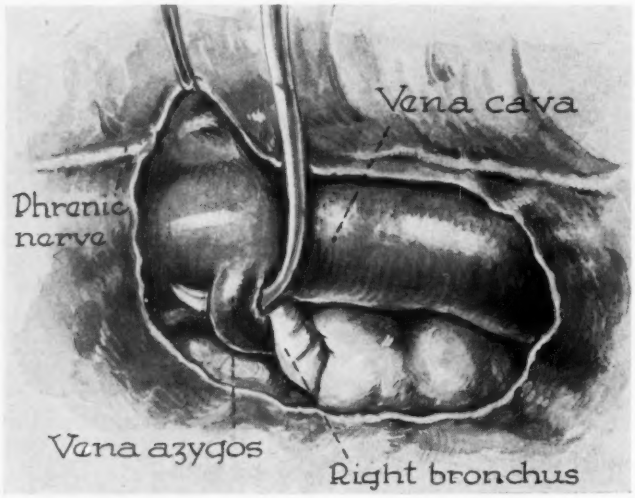


Fig. 5.—Drawing showing exposure and isolation of azygos vein.

Mass ligation of the hilum was condemned as an unsurgical procedure and one which will be followed by bad results in the majority of cases because it does not permit removal of the mediastinal lymph nodes. Moreover, in some cases it does not permit the complete removal of the tumor. In the anterior approach the first structure to be isolated is the pulmonary artery, which is separated from the bronchus and the superior pulmonary vein. However, on the right side, both in the

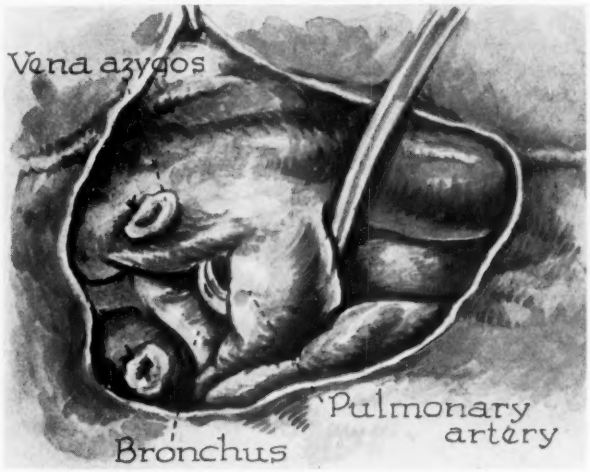


Fig. 6.—Drawing showing exposure and isolation of pulmonary artery. The Semb dissector greatly facilitates carrying ligatures around the hilar vessels.

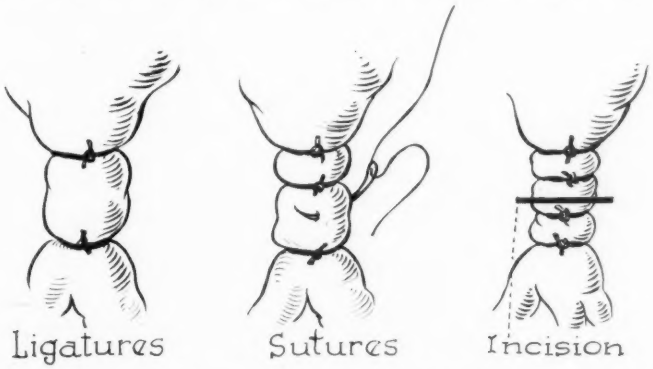


Fig. 7.—Diagrammatic illustration of technique employed in individual isolation and ligation of hilar structures. The pulmonary artery and pulmonary veins are divided between double ligation and transfixion sutures.

anterior and in the posterior approach, as a preliminary procedure, the isolation, ligation, and division of the azygos vein which extends over the right main stem bronchus and in the angle between it and the eparterial bronchus are considered highly desirable (Fig. 5). Failure to do this may lead to its injury with distressing and even fatal hemorrhage. Isolation of the hilar structures is performed principally by blunt dissection using small gauze pledgets and the curved Semb

dissector. After isolation of the pulmonary artery it is doubly transfixed and doubly ligated, following which it is divided between the two transfixed sutures and ligatures (Figs. 6 and 7). Davidson[38] recently has described a special ligature-carrier instrument for facilitating the isolation and ligation of the hilar vessels. However, in our experience the Semb dissector has been found most satisfactory (Fig. 6).

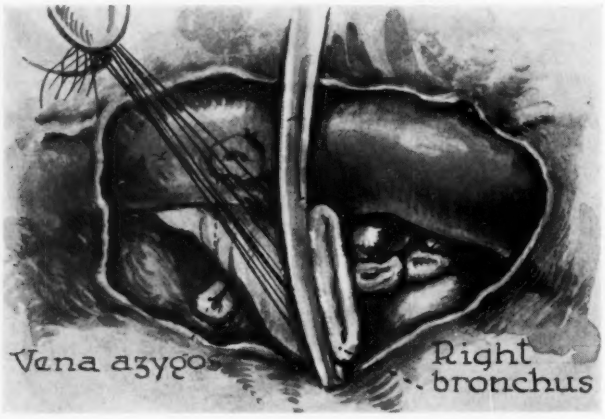


Fig. 8.—Drawing illustrating technique of closure of bronchial stump. The first row of mattress sutures of No. 2 silk is placed just proximal to the crushing clamp.

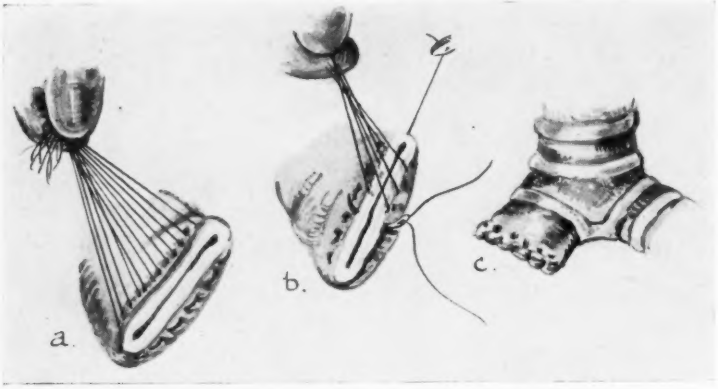


Fig. 9.—Drawing showing technique of closure of bronchial stump. *a*, The mattress sutures of the first row are tied after removal of the clamp. *b*, The interrupted sutures of the second row are introduced just distal to the first row and *c* tied over the end of the bronchus.

It has been clinically and experimentally observed by some that certain cardiac or respiratory disturbances may occur following manipulation and traction on the hilar structures.[43, 101, 110, 113, 119] Whereas many believe that it is desirable to inject novocain around the hilar structures before their isolation and manipulation, it is our opinion that the occasional manifestations during such a manipulative procedure are due to mechanical factors rather than to reflex stimulation of the vagus or sympathetic nerves. This opinion is based on the fact that in our series of cases, although in the isolation of the hilar structures traction

on the vessels has been done, no disturbances have been observed except in one instance. We agree with Edwards[50] that traction, particularly on the pulmonary artery, may mechanically compress the main branch and produce these disturbances in cardiac and respiratory action.

Fig. 10.—Photograph of median section of trachea and bronchi of patient dying 12 days after left pneumonectomy of pneumonia and pericarditis. The bronchial stump, which was closed at operation according to the technique described in the text, shows very satisfactory healing.

After division of the pulmonary artery, as suggested by Rienhoff,[134] it is desirable to isolate the bronchus and pass a ligature around it. This is tightened in order to prevent spillage of the contents within the involved lung into the trachea and the opposite bronchial tree. The superior pulmonary vein is then isolated, doubly transfixed, ligated, and divided. The bronchus is then further freed from its sur-

rounding structures, care being taken not to injure the bronchial vessels. A crushing clamp is placed high on the bronchus just distal to the bifurcation of the trachea. Another clamp is placed just distal to this and the bronchus is divided between the two. The bronchus is closed by means of interrupted silk sutures introduced in two layers.

Fig. 11.—Photograph of median section of trachea and bronchi of patient dying of recurrence 10 months after left pneumonectomy. The excellent closure of the bronchial stump, which was completely lined with mucosa, may be readily observed in spite of the surrounding recurrent carcinomatous tissue.

The first layer is a mattress suture of No. 2 silk, placed just proximal to the clamp (Fig. 8). All of the sutures are introduced before the clamp is removed. After all of the sutures have been installed, extending from one side of the bronchus to the other, the clamp is removed and the sutures are tied. Following this, the interrupted No. 1

silk sutures of a second row are introduced just distal to the first row and tied over the end of the bronchus (Fig. 9). Whereas numerous methods[165] for closure of the bronchial stump have been suggested, many of which are ingenious and complicated, in our experience this has been the most satisfactory (Figs. 10 and 11). The short inferior pulmonary vein is then isolated, doubly transfixed, and ligated. Occasionally, because of the short length of the inferior pulmonary vein, a distal ligation is not practical. In such an instance a crushing clamp is placed in the pulmonary parenchyma just distal to the transfixion

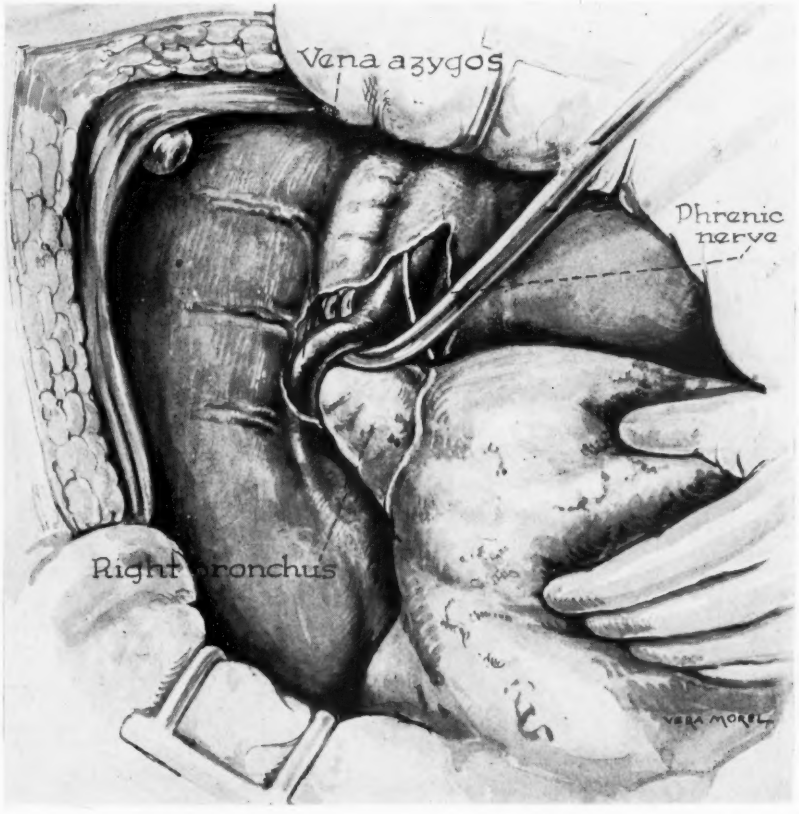


Fig. 12.—Drawing illustrating exposure of hilar structures through posterolateral approach. The mediastinal pleura over the hilum is incised posteriorly and superiorly and the flaps mobilized. The azygos vein is the first structure to be isolated, ligated, and divided.

sutures and ligatures and the vein divided between them. Finally the posterior mediastinal pleura is incised, following which the lung is removed. In the posterior approach the technique of isolation, division, and closure of the hilar structures is similar but the order of approach is different. Here, as anteriorly, the first structure to be divided on the right side is the vena azygos (Fig. 12). Following this the bronchus is isolated, clamped, and divided. The proximal portion of the bronchus is closed, the distal clamp being allowed to remain in place to act as a

retractor in facilitating exposure of the hilar structures. The pulmonary artery is then isolated, ligated, and divided, following which the superior pulmonary vein and finally the inferior pulmonary vein are similarly treated (Figs. 13 and 14).

After removal of the lung, the mediastinal lymph nodes are extirpated in their entirety. In this way metastases to these structures can be removed. Their deeply pigmented character greatly facilitates their recognition and isolation. If the bronchial vessels have not been ligated previously, this should be done. Following the complete extirpation of all the mediastinal lymph nodes, careful pleuralization of the mediastinum is imperative. The edges of the divided mediastinal pleura are approximated, thus covering with pleura the stumps of the ligated

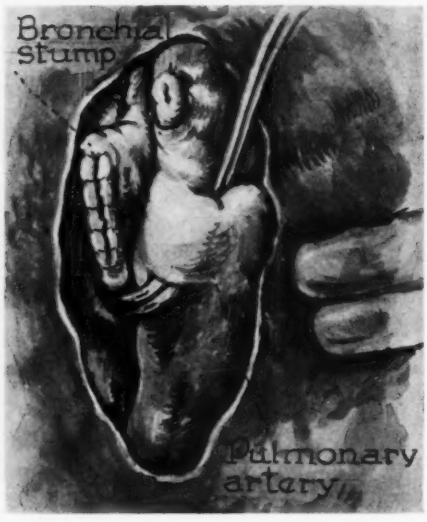


Fig. 13.

Fig. 14.

Fig. 13.—Drawing illustrating technique of isolation and ligation of hilar structures through posterolateral approach. After ligation and division of the azygos vein the bronchus is exposed and divided between clamps and the proximal stump ligated as previously described. The pulmonary artery is then isolated and divided between ligatures as described in the anterior approach.

Fig. 14.—Drawing illustrating technique of exposure and isolation of the inferior pulmonary vein through posterolateral approach. This is the final structure to be divided, the superior pulmonary vein having been sectioned between ligatures previously.

vessels and bronchus (Fig. 15). The significance of this important step lies in the fact that the danger of infection is minimized and prompt healing of the bronchial stump augmented. In those cases in which a large amount of the mediastinal pleura has been extirpated it is necessary to obtain a flap from an adjacent portion of the mediastinum or the pericardium in order to cover the ligated stumps, as originally suggested by Rienhoff (Fig. 16).

The thoracic wall is closed in layers by first placing No. 3 silk sutures around the adjacent rib or through holes made in the ribs. Following this, the pleura and intercostal muscles are approximated by quilting

cotton. The retention sutures which are buried are then tied and the pectoral muscles are approximated by means of quilting cotton. The skin edges are brought together with a continuous cotton suture. No drainage is instituted, because we believe with Rienhoff that filling of the pleural cavity with fibrinous exudate is important in the obliteration of the cavity (Figs. 17-19). Thoracoplasty has not been found necessary and subsequently there is little or no disfigurement of the chest (Fig. 20). We have not observed infection except in one case in which the bronchial stump "blew out" in a patient who had received

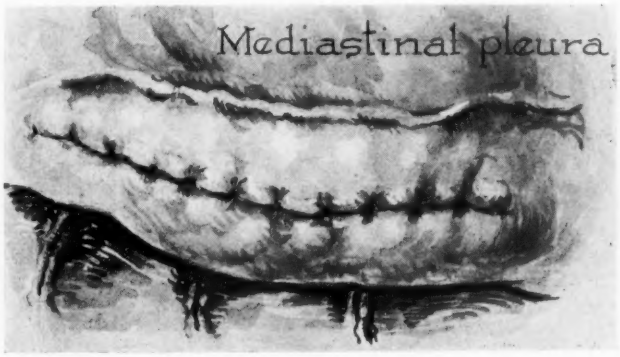


Fig. 15.—Drawing showing pleuralization of mediastinum following complete extirpation of mediastinal lymph nodes. The edges of the mediastinal pleural flaps are approximated, thus covering with pleura the stumps of the ligated vessels and bronchus.

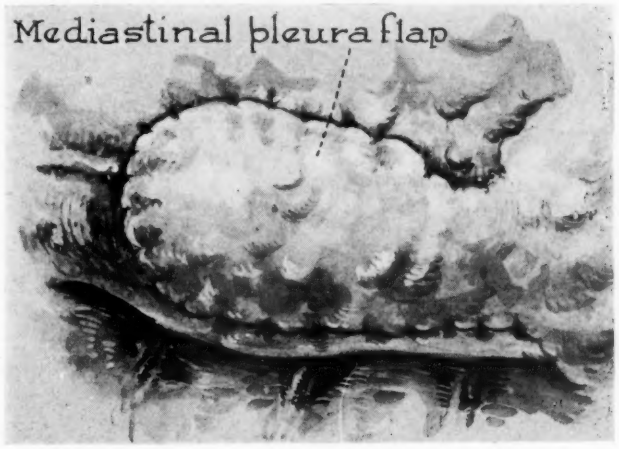


Fig. 16.—Drawing showing methods of covering the stumps of the ligated vessels and bronchus with a mediastinal pleural flap obtained from an adjacent portion of the mediastinum or the pericardium.

a great deal of preoperative irradiation and in whom there was no attempt at healing, both in the mediastinal and in the parietal wounds, presumably due to the extensive irradiation.

After the patient is returned to bed, the foot of the bed is elevated from 12 to 18 inches to facilitate the emptying of the tracheobronchial tree of any secretion. Oxygen is administered by means of a mask, and the patient is given fluids by means of an intravenous drip. Al-

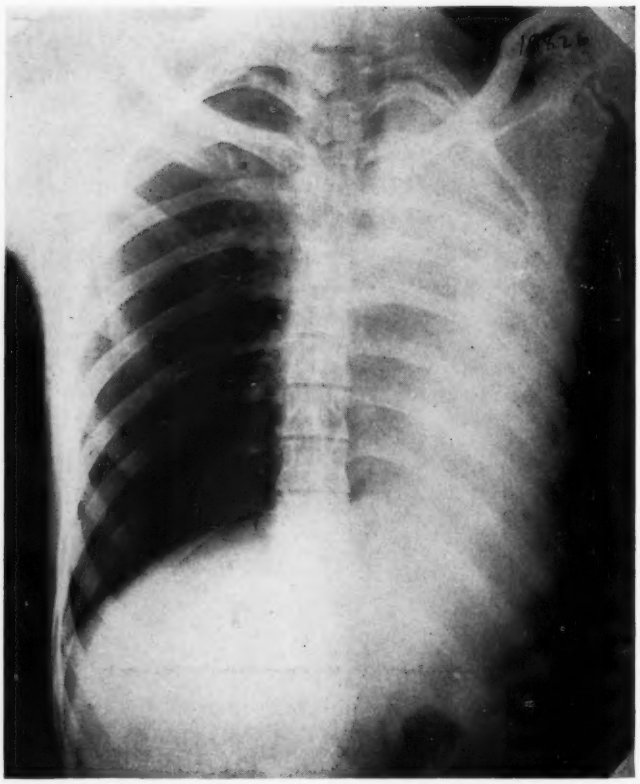


Fig. 17.—Anteroposterior roentgenogram of chest of patient who had left total pneumonectomy 2 years previously for primary sarcoma of left lung. This patient is well now 4½ years after operation with no evidence of recurrence. Roentgenogram shows obliteration of left pleural cavity and shifting of mediastinum to left.

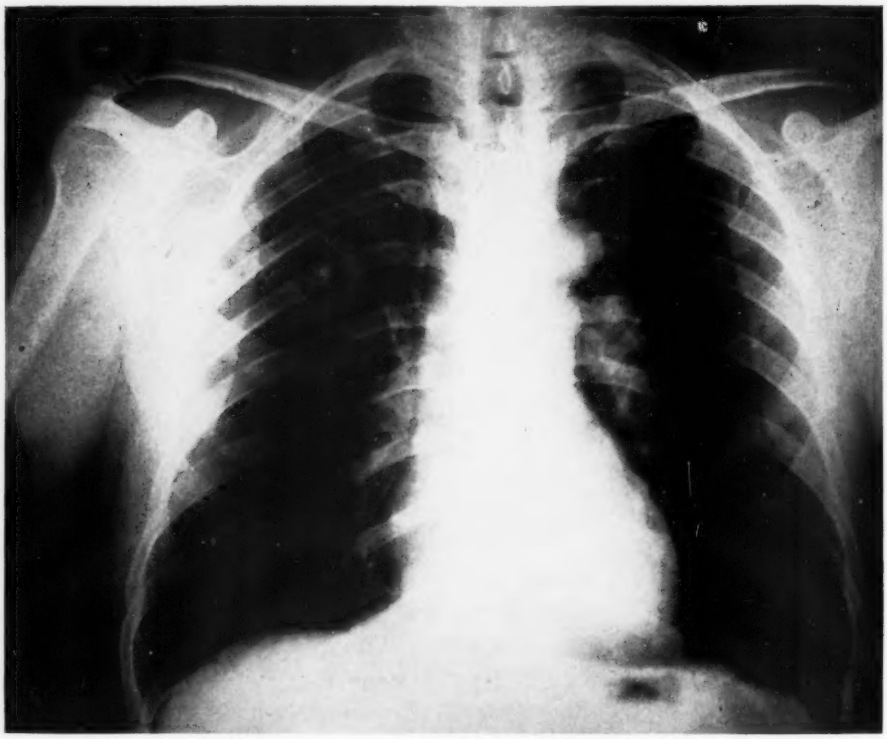


Fig. 18.—Anteroposterior roentgenogram of chest of patient with carcinoma involving left upper lobe bronchus as characterized by rounded irregular shadow near hilum on left side.

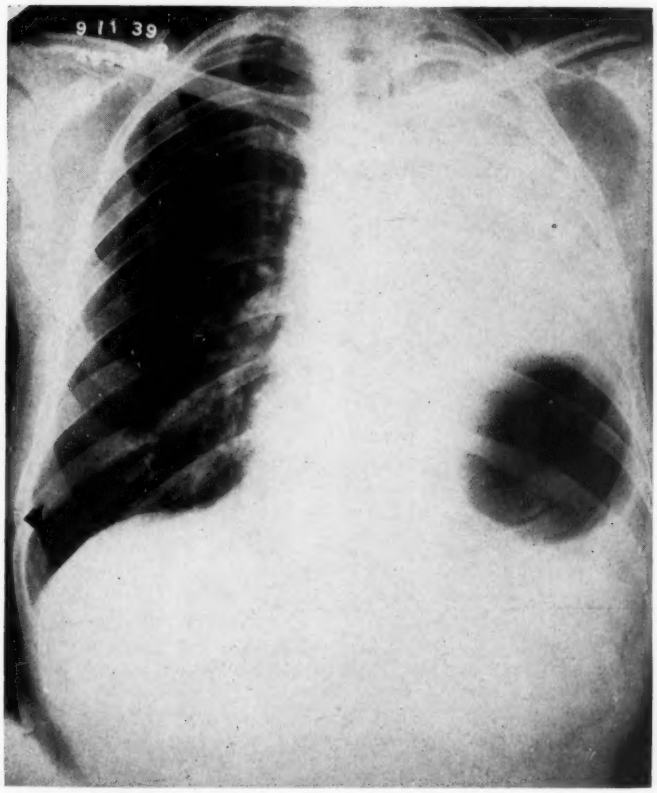


Fig. 19.—Anteroposterior roentgenogram of chest of patient referred to in Fig. 18 taken approximately six weeks after left pneumonectomy. The obliteration of the left pleural cavity is considerably facilitated by the elevation of the left leaf of the diaphragm.

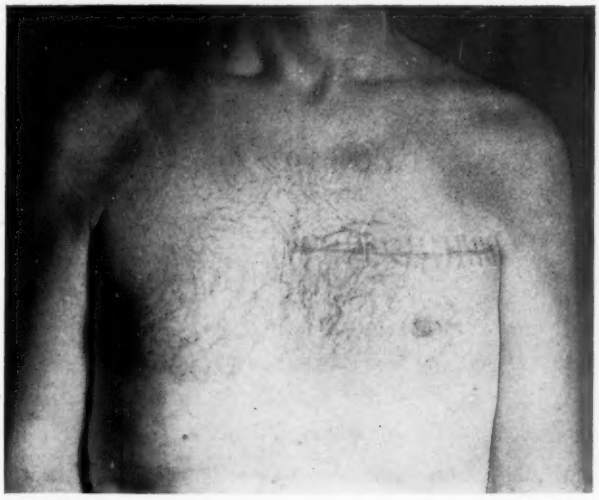
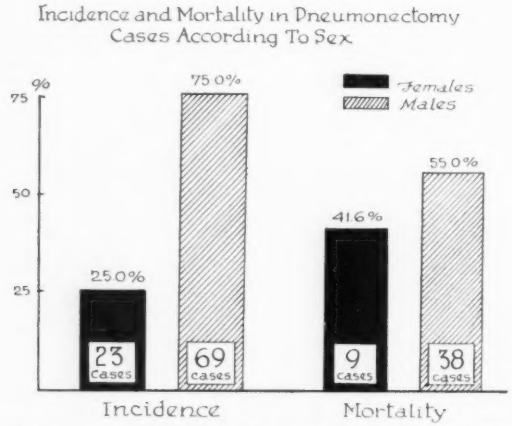
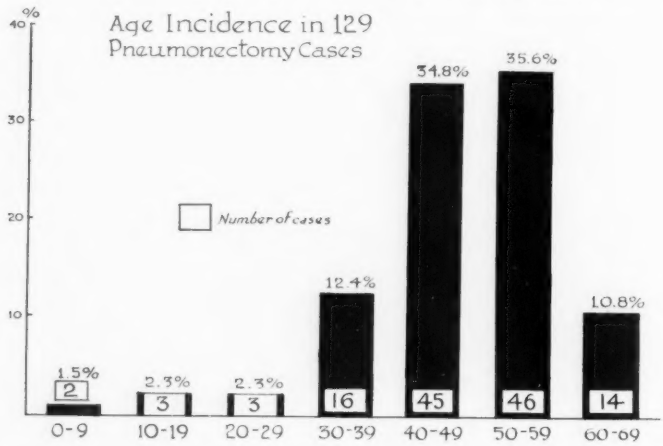


Fig. 20.—Photograph of patient referred to in Figs. 18 and 19 taken approximately 6 weeks after left pneumonectomy. The thin line scar may be observed over the third interspace, but there is no disfigurement of the chest or limitation of motion. The patient is still living and active in his work.

most invariably after pneumonectomy the patient receives 500 to 1,000 c.c. of whole blood, depending upon the amount of blood lost during the operation. The patient is given adrenal cortical extract every two hours and vitamins C and B are continued during the postoperative period. Only a sufficient amount of morphine to control pain is administered as the depressing effect on the cough reflex is undesirable.



Graph I.—Graphic representation of relative incidence and mortality according to sex in 92 collected cases of pneumonectomy including our cases.



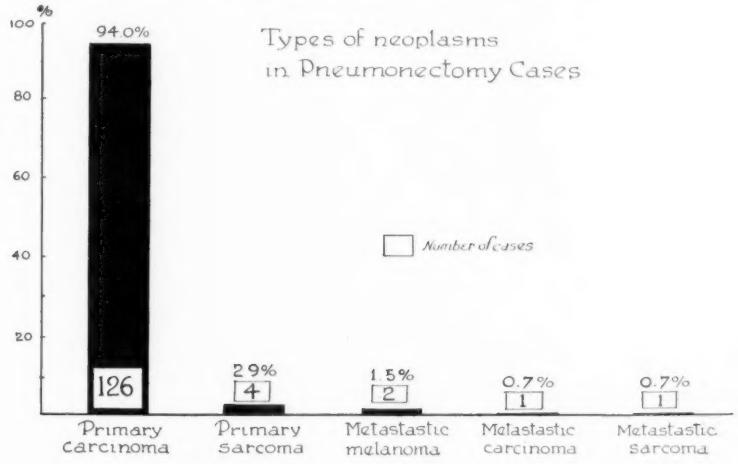
Graph II.—Graphic representation of age incidence according to decades in 129 collected cases of pneumonectomy including our cases.

ANALYSES OF CASES

In a previous publication we[115] collected and analyzed 79 reported cases of total pneumonectomy for neoplastic disease. In addition to this number we reported 7 of our own, making a total of 86 cases. Since then there have been reported 60 additional cases and we have had 12 more cases, making a total of 139 collected cases (166) and 19 of our cases, or a grand total of 158 cases. This approximately twofold increase of reported cases of pneumonectomy for malignant disease in a period of less than two years is a gratifying indication of the surgical

significance of this condition. An analysis of these cases reveals some interesting findings.

Of 92 cases in which the sex was stated, 23 (25 per cent) were females and 69 (75 per cent) were males (Graph I). In our series of 19 cases, 4 were in females and 15 were in males. This is somewhat similar to the respective incidences of the previously collected cases[115] and approximately the general sex incidence in carcinoma of the lung. In a collected series of 8,575 cases of primary carcinoma of the lung there were 6,769 (79.9 per cent) males and 1,806 (21 per cent) females.[116, 117] The age of patients was stated in 129 cases. The highest age incidences, 34.8 per cent and 35.6 per cent, were in the fifth and six decades, respectively (Graph II). Of particular interest is the fact that 18.5 per cent, or almost one-fifth, of the cases were below 40 years of age. There were two patients, both with sarcoma, in the first decade, one being 3½ years of

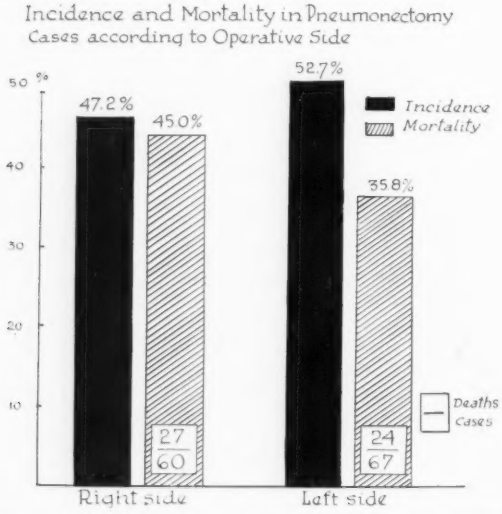


Graph III.—Graphic representation of types of neoplasm in 134 collected cases of pneumonectomy including our cases.

age and the other 5½ years. The oldest patient was 69 years of age. The age incidence in the pneumonectomy cases differs somewhat from the general incidence. For example, in a series of 4,307 collected cases the respective incidences in the fifth, sixth, and seventh decades were 25.4 per cent, 34.1 per cent, and 20 per cent; whereas, in the pneumonectomy cases they were 34.8 per cent, 35.6 per cent, and 10.8 per cent. Thus, in the latter there was a higher incidence in the youngest of these decades and a lower in the oldest. The explanation for this probably lies in the fact that the younger cases are better surgical risks.

The type of neoplasm was stated in 134 cases and of this number 126 (94 per cent) were primary carcinoma, 4 (2.9 per cent) were sarcoma, 2 (1.5 per cent) were metastatic melanoma, 1 (0.7 per cent) was a metastatic carcinoma, and 1 (0.7 per cent) was a metastatic sarcoma (Graph III).

The site of involvement was stated in 127 cases. Of this number 60 (47.2 per cent) were in the right side and 67 (52.7 per cent) were in the left (Graph IV). This is somewhat similar to the previously collected group, but it is in direct contrast to the general incidence in which it has been found that the greatest frequency of involvement is in the right



Graph IV.—Graphic representation of relative incidence and mortality according to operative side in 127 collected cases of pneumonectomy including our cases.

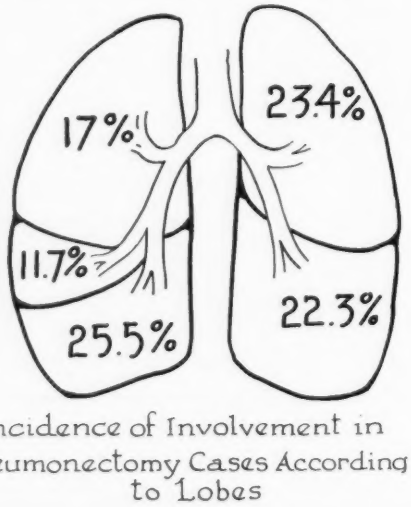
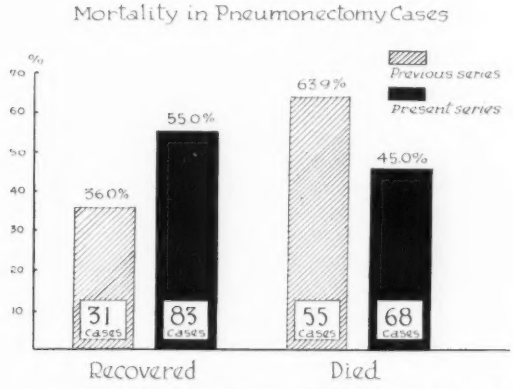


Fig. 21.—Diagrammatic representation of incidence of involvement in pneumonectomy cases according to lobes.

lung. Thus, in a collected series[117] of 4,732 cases, 2,761 (58.3 per cent) involved the right lung and 1,971 (41.6 per cent) involved the left. Whether left lung lesions are more likely to be operable is of speculative interest. The involvement according to lobes was stated in 79 cases. The greatest incidence, 25.5 per cent, was found to be in the right lower

lobe and the next in order of frequency, the left upper, the left lower, the right upper, and the right middle (Fig. 21). This also differs from the general incidence of involvement. In an analysis of 784 cases Fischer[54] found that the right upper lobe was most frequently involved and the next in order of frequency were the left upper, right lower, left lower, and middle lobes.

Of the total number of 151 cases in which the results of the operation were stated, 83 (55 per cent) recovered and 68 (45 per cent) died (Graph V). In the previously collected series the mortality was 63.9 per cent. Thus, the general mortality in a period of less than two years has been reduced almost one-fifth. This gratifying fact clearly reflects the rapid advances in thoracic surgery and favorably indicates that with greater experience in this difficult surgical endeavor the mortality undoubtedly will be further decreased.

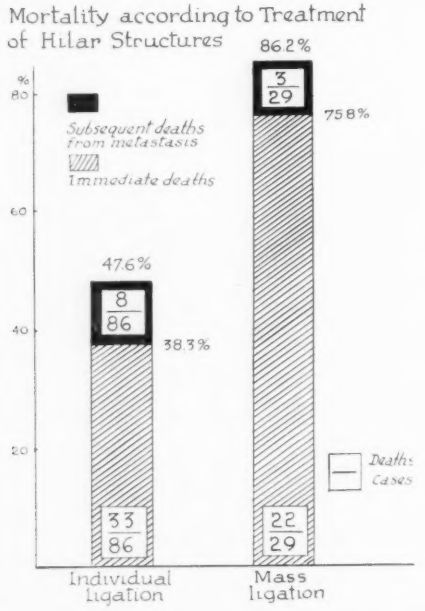


Graph V.—Graphic representation of total mortality in previous and present series of collected cases including our cases.

There are a number of factors which seem to have a significant influence on the mortality in addition to the general condition of the patient and certain technical considerations. The mortality according to sex reveals a lower death rate in females. Of 23 females, 9 (41.6 per cent) died; and of 69 males, 38 (55 per cent) died (Graph I). The exact significance of this fact is difficult to explain. Attention was directed in a previous publication to the fact that the mortality is greater in right-sided lesions. This is further confirmed in the present series. Of 60 right-sided lesions, 27 (45 per cent) died; whereas, of 67 left-sided lesions, 29 (35.8 per cent) died (Graph IV). Technically the operation is more difficult on the right than on the left side, principally due to the fact that on the right side the vena azygos crosses over the eparterial bronchus, usually making mobilization and isolation of the right main stem bronchus difficult. Experimentally it has also been demonstrated that right pneumonectomy is a more serious procedure than left pneumonectomy,[50] and this has been explained on the basis of greater size and aerating surface of the right

lung. Of significance in this regard is the demonstration of Jacobaeus and his co-workers[19, 80] by bronchosperometric experiments that the functional capacities of the respective lungs corresponded to the anatomical fact that the right lung constitutes 54 per cent and the left lung 46 per cent of the total volume of both lungs.

The method of treatment of the hilum also influences the prognosis. Of 86 collected cases, including all of ours, in which individual ligation of the hilar structures was done, 33 (38.3 per cent) died; whereas, of 29 collected cases in which mass ligation was used, 22 (75.8 per cent) died (Graph VI). If there are added to these figures subsequent deaths from metastases, the corresponding mortality rates become 47.6 per



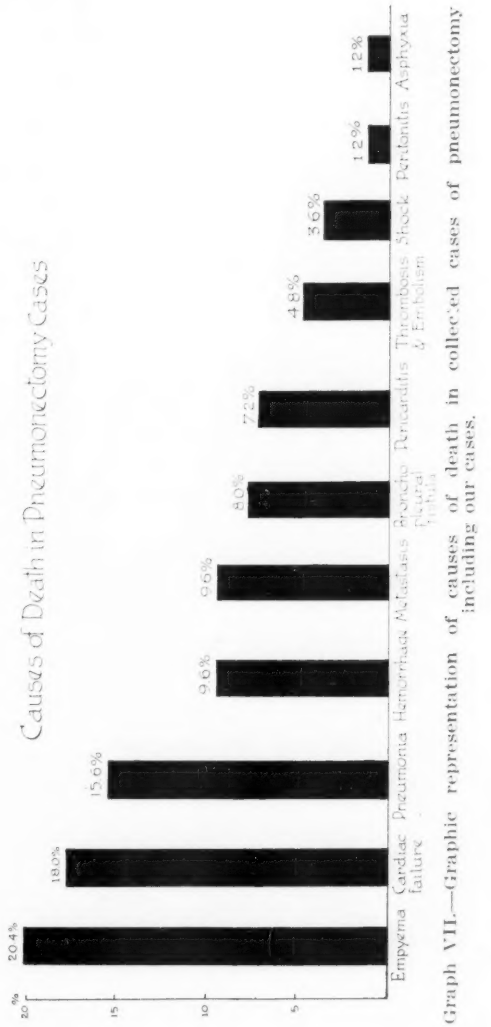
Graph VI.—Graphic representation of mortality according to treatment of hilar structures in 115 collected cases of pneumonectomy including our cases.

cent and 86.2 per cent. These contrasting mortality incidences emphasize further the superiority of individual ligation of the hilar structures over mass ligation.

The causes of death following pneumonectomy are principally due to cardiac and pleuropulmonary complications. In the collected series, including our cases, empyema, cardiac failure, and pneumonia were the most frequent causes of death occurring in incidences of 20.4 per cent, 18 per cent, and 15.6 per cent, respectively (Graph VII). Hemorrhage and metastasis were stated as causes of death in 9.6 per cent each. Bronchopleural fistula was a cause of death in 8 per cent, pericarditis in 7.2 per cent, thrombosis and embolism in 4.8 per cent, shock in 3.6 per cent, and peritonitis and asphyxia in 1.2 per cent each.

These latter two cases of deaths appeared in our cases and have been referred to in a previous publication.[115]

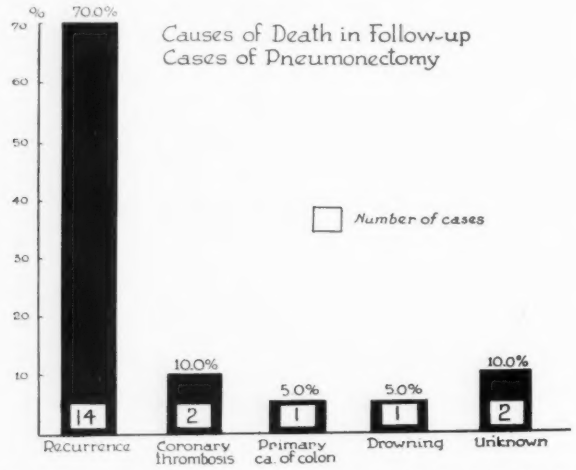
Whereas in any surgical procedure the operative mortality is important, in the surgical treatment of malignancy the consideration of follow-up results is of even greater significance. Obviously primary carcinoma of the lung is of too recent development to permit adequate



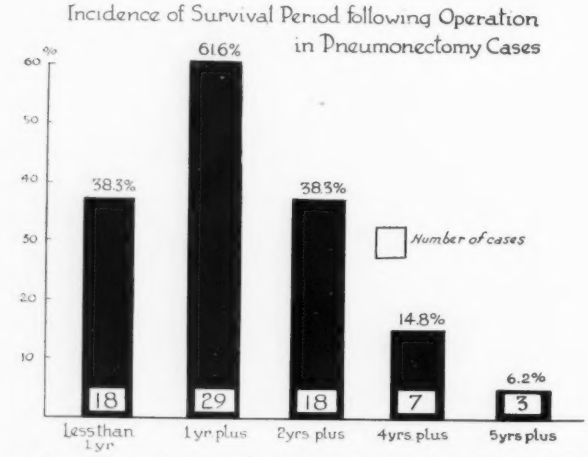
Graph VII.—Graphic representation of causes of death in collected cases of pneumonectomy including our cases.

evaluation on the basis of large statistical analyses. It should be realized that the first successful pneumonectomy was done only seven years ago. However, it may be interesting to observe the results of available statistics. Of a series of 83 collected cases, including 10 of ours, which recovered following operation, follow-up data are available in 67. Of this number, 47 (70.1 per cent) were still living at the time of the report and 20 (29.8 per cent) were dead. In our series of 10 recoveries

there have been 3 subsequent deaths, 2 of which were definitely due to recurrence and the third was probably due to a similar cause. These patients survived 10 months, 9 months, and 3 months, respectively. Of the 20 collected cases, including ours, in the follow-up series which died, the cause of death was recurrence in 14 (70 per cent), coronary thrombosis in 2 (10 per cent), primary carcinoma of the colon in 1



Graph VIII.—Graphic representation of causes of death in 20 collected and our cases with follow-up.



Graph IX.—Graphic representation of incidence of survival periods following operation in 47 collected and our cases with follow-up.

(5 per cent), drowning in 1 (5 per cent), and unknown in 2 (10 per cent). (Graph VIII.) In this group the shortest survival period following operation was 3 months, the longest 3½ years, and the average 1 year. Thirteen cases had survival periods of less than 1 year and 3 cases more than 2 years.

Of the 47 collected cases, including ours, that are still living, 18 (38.3 per cent) have survival periods of less than 1 year and 29 (61.6

per cent) of more than 1 year. Of the latter number, 18 (38.3 per cent) are living 2 years after operation, 7 (14.8 per cent) 4 years after operation, and 3 (6.2 per cent) 5 years after operation (Graph IX). The shortest period is 3 months, the longest 6+ years, and the average 18.8 months. In our series of 7 cases which are still living the survival periods are 4½ years, 2 years, 1½ years, 14 months, 10 months, 8 months, and 7 months.

SUMMARY

1. The increasing interest in carcinoma of the lung is probably due to several factors, among the most important of which are the apparently increasing incidence, the relative frequency, the rapid advances in thoracic surgery, and the demonstrated feasibility of surgical therapy.

2. It is generally agreed that the only curative treatment of primary carcinoma of the lung is surgical extirpation. Irradiation therapy is of little, if any, value and there is some evidence that it may be actually detrimental.

3. Total removal of the involved lung and the mediastinal lymph nodes is the most rational surgical procedure. This can be adequately performed only by individual ligation of the hilar structures.

4. The factors influencing operability in primary carcinoma of the lung are briefly reviewed. Emphasis is placed on the fact that borderline cases should always be given the benefit of exploration, even at the risk of finding a large number inoperable, because it is the only means by which operability can be determined absolutely in these instances. In the collected series 49 per cent were operable and in our series 63.3 per cent were operable.

5. The preparatory measures and type of anesthesia in pneumonectomy are discussed. The various approaches used in pneumonectomy are described, illustrated, and evaluated. The technique of exposure, isolation, and individual ligation of the hilar structures is described and illustrated.

6. An analysis of 139 collected and 19 personal cases of total pneumonectomy for neoplastic disease of the lung is presented. The sex incidence showed a predominance of males (75 per cent). The age incidence was highest in the fifth and sixth decades. Primary carcinoma comprised 94 per cent of the cases, primary sarcoma 2.9 per cent, metastatic melanoma 1.5 per cent, metastatic carcinoma 0.7 per cent, metastatic sarcoma 0.7 per cent. Right-sided lesions occurred in 47.2 per cent and left-sided in 52.7 per cent. The general mortality was 45 per cent. The various factors influencing the operative mortality are discussed and critically analyzed. The most frequent causes of death are principally due to cardiac and pleuropulmonary com-

plications. The follow-up results in 67 of 83 collected cases, including ours, are presented. Of this number 70 per cent are still living. In our series 7 of the 10 patients who recovered operation are still living, the longest survival being 4½ years. The average survival period following operation in the collected cases which recovered is 18.8 months.

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164. See Ref. 21, 59, 74, 75, 82, 84, 85, 128, 137, 139, 141, 146, 149, 150, 154, 157.
165. See Ref. 2, 3, 16, 18, 38, 52, 60, 68, 69, 70, 81, 83, 96, 106, 112, 133, 138, 140, 147, 153.
166. See Ref. 1, 5-11, 15, 17, 22, 24, 30-35, 40-42, 44-49, 53, 55, 57, 58, 61-66, 72, 73, 77-79, 90, 91, 94, 97, 102, 103, 107-109, 114, 120-127, 131-135, 142, 143, 152, 156, 161.

Erratum

In the article by Prof. Dr. Eugene Pólya, Budapest, Hungary, entitled "Simple Apparatus for the Relief of Some Palsies of the Upper Extremities" which appeared in the September issue of the JOURNAL, the plate upon which appear Figs. 1, 2, and 3 has been printed upside down, thus reversing the figures. The legends are correct if the reader will consider the plate inverted.

Editorial

Von Ludwig's Angina

A LITTLE over a century ago (1836) an unusually popular queen died. Her death was due to what was then described as a "sublingual phlegmon." This was Queen Catherine of Württemberg. It is natural to presume the cause of her death was then fully discussed by both the laity and by the medical profession. Shortly after Queen Catherine's death, Professor Wilhelm Friedrich von Ludwig (1790-1865), Vice Director and Liebartz of Stuttgart, made an address before a medical group assembled in that city. It is not surprising that he selected as the subject of his address the cause of the recent death of their beloved queen. Ludwig must have made a most impressive and illuminating explanation of the disease, as a year later Camerer gave the title of "von Ludwig's angina" to the condition, and, as such, it has now been known for over one hundred years.

In 1892 there was a debate between Delormé and Nélaton relative to the propriety of retaining Ludwig's name in association with this disease.

Again in 1929, Ashhurst, in an address as the invited guest of the Western Surgical Association on the subject of "Ludwig's Angina," stated that the medical profession in its attitude toward the retention of any doctor's name in association with a disease was largely divided into two groups: The first, those who followed the teachings of Hippocrates in objecting to the unnecessary multiplication of names of diseases and preferred to assign the so-called "new diseases" to their proper places under already recognized pathologic processes; the second group, the Cridians (of whom I had never heard until I read Ashhurst's address). With them, every new symptom and every new complication constitutes a new disease.

It is interesting to recall that Ludwig's angle, that angle situated between the manubrium and the gladiolus, derived its name from Daniel Ludwig (1625-1680), a German anatomist. Furthermore, Ludwig's ganglion, a ganglion connected with the cardiac plexus and situated near the right auricle of the heart, obtained its name from still a different Ludwig; namely, Karl Friedrick Wilhelm Ludwig, of Leipzig, a German physiologist (1816-1899). However, Karl Friedrick Wilhelm Ludwig's name is not attached to any of the many recording instruments which he introduced into physiology.

The expression "von Ludwig's angina" is with us today, and no matter what our individual views might be concerning the propriety of the

association of the names of individuals with titles of diseases, I believe the expression, Ludwig's angina is going to exist for many more years to come.

When one reviews the various mortality percentages associated with the treatment of this disease, there can be but one conclusion reached; namely, there must be at the present time a very wide difference of opinion as to what actually constitutes a case of von Ludwig's angina, for there is not sufficient difference to be found in the various methods of treatment advocated to explain the wide difference of mortality statistics, the lowest of these mortality statistics reported being 5 per cent, and the highest 74 per cent. For this reason, it might be interesting to quote the requirements that Ludwig himself thought necessary in order to establish the diagnosis of Ludwig's angina. These were:

"1. There should be inflammation of the deep cellular tissues under the tongue.

"2. This inflammation should begin around the submaxillary salivary gland.

"3. This inflammation should subsequently invade the neck and the floor of the mouth.

"4. That this condition should run a course which grows progressively worse with death in ten to twelve days or gradual recovery."

This description of the condition is sufficiently indefinite to explain the present-day mental confusion regarding what actually constitutes the diagnosis of von Ludwig's angina. It also makes us wonder as to how much the great popularity of Queen Catherine had to do with the continuation of the use of this name.

A recent compilation of statistics from various reports in literature in which the cause was mentioned reveals that extraction of the lower molar teeth preceded the beginning of infections in the deep structures of the tongue in 82 per cent of cases. Calculus in the duct of the submaxillary salivary gland, fracture of lower mandible through abscess cavities, injury from foreign bodies in mouth, etc., have also been found as etiologic factors.

The explanation of the frequency with which these deep infections follow extractions of the lower molars is to be found in the fact that the lower molars are set off center and toward the tongue in the mandible bone. The remaining teeth are also set off center but toward the outer (labial) side. This anatomical difference explains why infection of the deep structures under the tongue takes placé more readily through the thin bony partition on the inner side than through the thick outer side of the mandible following extraction of the lower molars. The reverse is true as regards the relationship of the remainder of the teeth. For this reason, infections following extractions of the anterior teeth are more apt to originate through the thin outer partition than they are to perforate through the thicker inner partition.

In addition to these differences in skeletal structure the firm attachment of the deep cervical fascia and the mylohyoid muscle to the lower inner edge of the inferior mandible confines infections rupturing through the inner side of the bone to the deep structures. When the infection through the bone ruptures to the outer side of the mandible, this fascia and muscle tend to confine the inflammation to the superficial structures.

For these reasons, infections following extractions of the anterior teeth are not apt to be as serious as those following the removal of the lower molars. If infection following extractions of the anterior group of teeth does not subside quickly, superficial fluctuation soon develops without general symptoms and the pus is easily released. Such a picture is the reverse of what is seen in infections of the deep structures under the tongue.

The use of sulfanilamide and its various derivatives can be employed to great advantage before the extraction of lower molars, especially if there is any infection present.

Cultures of the infected gums and, if possible, of the abscess associated with the teeth should be a basis of selection of which one of the sulfanilamide compounds should be employed.

After extraction of unerupted teeth, zinc peroxide, as prepared by Meleney's method, has proved of benefit in preventing postextraction infections. In such cases there is frequently found an ulcer on the undersurface of the gum which has to be incised in order to expose the tooth. An anerobic hemolytic streptococcus is usually present in such ulcers.

The closest possible cooperation between dentist and surgeon is imperative. If a hard painful swelling develops under the tongue after the extraction of a lower molar, incision and drainage should be instituted at an early period. One should not wait for the fluctuation which does not usually occur and, of course, should not postpone surgical relief until the patient is partially strangled.

If the tension of tissues is sufficiently great to produce elevation of the hyoid bone, the fibers of the mylohyoid muscle should be cut transversely so as to give almost immediate relief from the "pull" on the trachea. Necrotic material, and, if indicated, the submaxillary salivary gland should be removed. In fact, everything should be done in order to release the tongue quickly from obstructing the air passages to the lung.

The most satisfactory incision in extreme cases is the one about one-half inch from the lower edge of the mandible, extending from one angle of the jaw to the other angle. Of course, in order to obtain relief it is necessary to incise widely the deep cervical fascia as well as to divide the mylohyoid muscle transversely.

A preliminary tracheotomy done with local anesthesia is sometimes indicated and, when done, the opening in the trachea can be used for a gas anesthetic of the surgeon's choice.

If intravenous anesthesia (preferably sodium pentothal) is given, it should be administered by the intermittent method. Apparently no bad results follow the giving of sodium pentothal to patients who have been taking sulfanilamide or any of its derivatives; this, in spite of the fact that sodium pentothal also contains sulfur and the addition of such to sulfanilamide might theoretically produce untoward results.

Helium employed as a vehicle to carry an anesthetic gas is not yet available by any practical method, but this gas can convey oxygen through a restricted aperture leading to the lungs. Oxygen should always be available and handy.

Certainly any infection following the extraction of a lower molar tooth should have the close cooperation and vigilant attention of both the dentist and the surgeon, for so frequently an apparently mild invasion of the structures under the tongue will develop quickly into a painful death of the patient unless tension and infection are quickly relieved by wide incision and free drainage.

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Roanoke, Va.

Recent Advances in Surgery

CONDUCTED BY ALFRED BLALOCK, M.D.

ACUTE PERFORATED GASTRODUODENAL ULCERATION

A STATISTICAL ANALYSIS AND REVIEW OF THE LITERATURE

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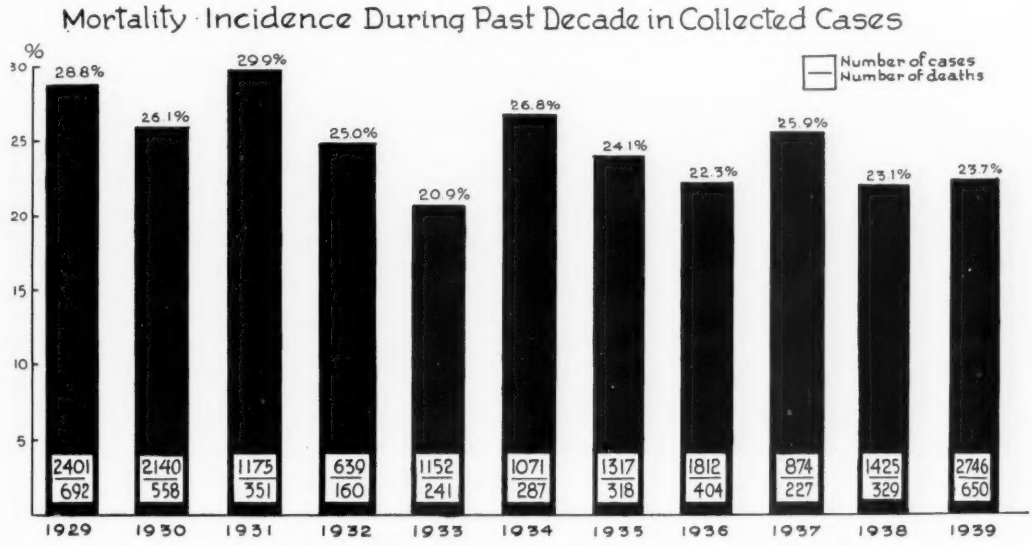
(From the Department of Surgery, School of Medicine, Tulane University)

(Continued from the November issue.)

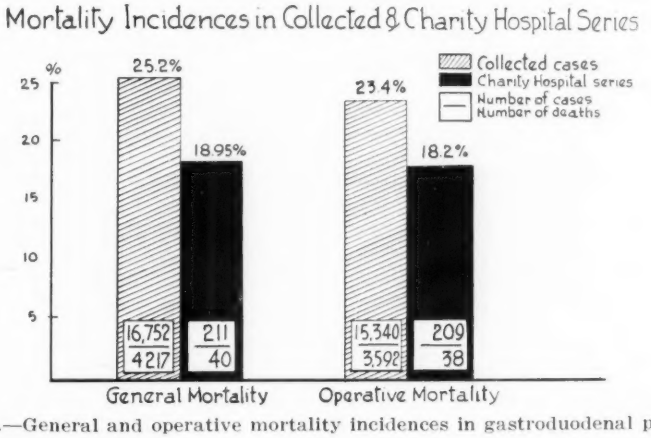
Prognosis.—The mortality in perforated gastroduodenal ulceration has diminished considerably since the turn of the century. In 1897 Mikulicz[419] collected 103 cases with a mortality of 68 per cent. In 1900 Weir[685] found the mortality in 51 collected cases of perforated duodenal ulcers was 90.2 per cent and Finney[203] in a collected series of 268 perforated gastric ulcers, including 232 previously reported by Tinker,[644] found that the mortality was 48 per cent. In 1901 Moynihan[435] reported 45 cases treated surgically with the astoundingly high mortality of 91.1 per cent. Brunner[84] in 1903 collected 387 cases with a total mortality of 48 per cent but expressed the belief that it was probably about 68 per cent. In 1908 Moynihan[437] recorded 27 cases of his own with a mortality of 34 per cent. In reviewing their 200 cases in 1912, the Edinburgh group of surgeons[96] found the mortality to be 39.5 per cent. In 1914 Shoemaker[597] reported a series of 784 cases with an operative mortality of 48 per cent; Brütt[85] in 1921 found the mortality to be 40 per cent in a series of 140 cases. Whereas, Gibson[241] in 1923 reported the low mortality of 16.6 per cent in 60 cases, Walker[676] and Blumenthal[57] presented larger series with mortality rates of 38.5 per cent and 40 per cent respectively. In the same year Speck[620] found that in a collected series of 3,224 cases the mortality was 42 per cent and in his own series 45 per cent. He also found that the mortality was 58 per cent from 1900 to 1910, 50 per cent from 1911 to 1920, and 23 per cent from 1921 to 1922. Similarly, Bager[21] in 1929 found that in an analysis of 1,495 cases admitted to the group of hospitals in Sweden the mortality decreased annually; thus, in 332 cases during 1916 to 1920, 35.3 per cent, and in 693 cases during 1921 to 1925, 27.1 per cent. Somewhat similar observations were made by Graves,[252, 253] who found that in the collected cases during the period 1907 to 1918 the mortality rate was about 52 per cent; from 1918 to 1926, 37 per cent; and from 1926 to 1931, 28 per cent. In his cases during these

corresponding periods the mortality incidences were 50.9, 20, and 16.6 per cent.

Whereas, during the first three decades of the present century the mortality decreased considerably, during the past decade it has diminished very slightly. Thus in a collected series of 2,140 cases reported during the year 1930 the mortality was 26.1 per cent, and in 2,746 cases reported in 1939 the mortality was 23.7 per cent, a differ-



Graph XII.—Annual mortality incidences during past decade according to collected series.



Graph XIII.—General and operative mortality incidences in gastroduodenal perforation.

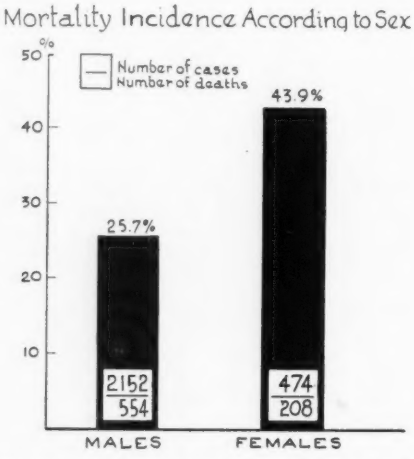
ence of only 2.4 per cent, or a decrease of only about 9 per cent (Graph XII). This is indeed a poor reflection of the numerous improvements in diagnostic methods, pre- and postoperative management, anesthesia, and surgical technique.

The total general mortality in a collected series of 16,752 cases[731] reported during the past decade was 25.2 per cent and the operative

mortality in a similar collected series of 15,340 cases[732] was 23.4 per cent (Graph XIII). In the Charity Hospital series these corresponding figures were 18.9 and 18.2 per cent.[474]

The prognosis in perforated gastroduodenal ulceration depends upon a number of factors. Obviously, the general condition of the patient as well as the pre- and postoperative management are important considerations. However, in addition to these it was found that sex, age, location of the lesion, time elapsing between the perforation and the institution of treatment, type of anesthetic employed, and the development of complications were among the most important factors in the prognosis.[147]

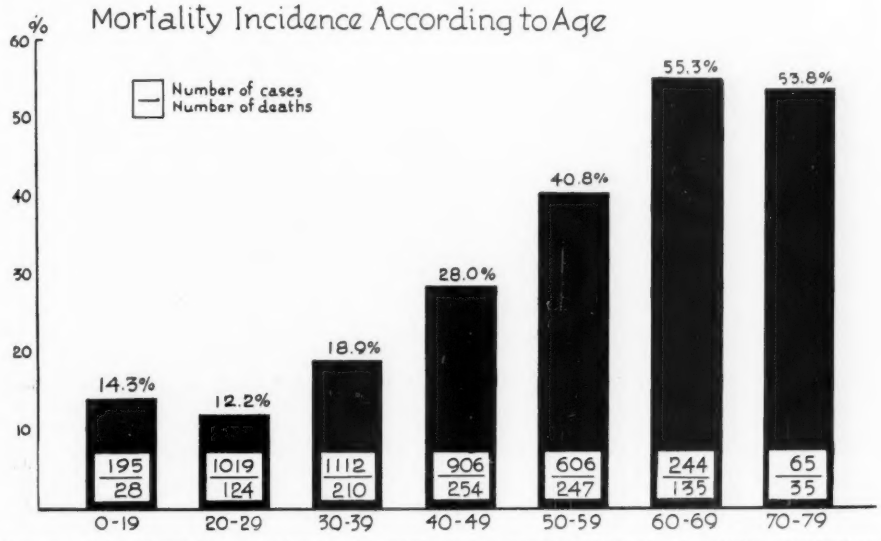
Apparently it has not been generally realized that the sex factor is significant in the prognosis of these perforations. Whereas, Gilmour and Saint[243] and Heim[277] reported slightly lower mortality incidences in the female sex, the majority of authors have made antithetical observations. In an analysis of 1,495 cases admitted to 50 hospitals in



Graph XIV.—Mortality incidence according to sex in 2,626 collected cases.

Sweden, Bager[21] found that of 406 females 175 (43.3 per cent) died and of 1,089 males 314 (28.8 per cent) died. In a series of 341 cases Judine[323] reported a mortality incidence of 37.5 per cent in females and 11.4 per cent in males. Lang[355] and Susman[633] also observed a lower mortality among males. In the Charity Hospital series the mortality in females was 25 per cent and in males 18.8 per cent.[147] In a collected series of 2,626 cases[21, 147, 243, 277, 323, 355, 633] it was found that of 474 females 208 (43.9 per cent) died and of 2,152 males 554 (25.7 per cent) died. (Graph XIV.) Thus it would appear that the prognosis is worse in the female sex, although the incidence of perforations is greater in the male. No satisfactory explanation for this fact has been offered. It is possible that the prognosis is worse in the female sex because they are more prone to develop gastric ulcer perforations which, as will be seen later, result in higher death rate.

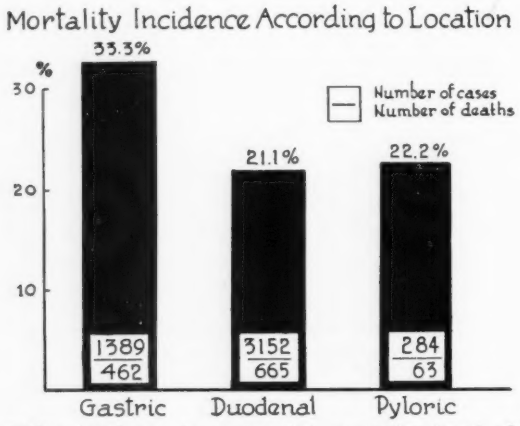
The significance of the age factor in the prognosis has long been realized. In 1917 Richardson[545] found that, whereas the mortality was 11.8 per cent in patients under 40 years of age, it was 53.5 per cent in patients over this age. In the large series analyzed by Bager[21] the mortality rate was 15.9 per cent in the second decade and increased in each succeeding decade to 62.8 per cent in the eighth. Semb[588] observed that in the first three decades the mortality was 44.4 per cent, in the next two decades it was 20 per cent, and in patients over 50 years of age it was 30.3 per cent. Graves[252] reported mortality incidences of 12.5, 23.6, and 50 per cent for these respective periods. In an unusually large personal series Judine[323] found that the mortality increased from 7.2 per cent in patients under 30 years to 33.3 per cent in patients over 50 years. In the collected series of 4,147 cases[733] the mortality was 12.5 per cent in patients under 30 years of age, 23 per cent in those between 30 and 50 years, 47.2 per cent in those between 50 and 70 years, and 53.8 per cent in those over 70 years. (Graph XV.)



Graph XV.—Mortality incidence in perforated gastroduodenal ulceration according to age in 4,147 collected cases.

The site of perforation is apparently a significant factor in the prognosis. Some observers have reported a higher mortality incidence in duodenal ulcer perforations, but the majority of authors have found higher death rates in gastric ulcer perforations. McGlannan and Bongardt[404] in 1927 reported a mortality incidence of 28.6 per cent in gastric ulcer perforations and 33.3 per cent in duodenal ulcer perforations Gibson[242] found these respective incidences to be 16.4 and 20.6 per cent and Cable[95] 21.4 and 32 per cent. Similar observations have been made by others,[159, 179, 192, 560, 594] although the differences were not as great. On the other hand, Collinson[116] in 1914 found that the mortality

incidence in gastric ulcer perforations was 53.8 per cent and in duodenal ulcer perforations 30.8 per cent. Somewhat similar figures were reported by Richardson.[545] An even greater contrast was observed by Southam.[619] In Bager's[21] large series these respective figures were 39.8 and 25.6 per cent and in Judine's[323] analysis 21.2 and 11.8 per cent. Others[136, 414, 441, 657] have also observed that the mortality was lower in duodenal ulcer perforations. In a series of 4,825 cases collected from the literature[734] it was found that of 1,389 gastric ulcer perforations 462 (33.3 per cent) died, of 3,152 duodenal ulcer perforations 665 (21.1 per cent) died, and of 284 pyloric ulcer perforations 63 (22.2 per cent) died. (Graph XVI.) From these statistics it appears that gastric ulcer perforations offer a worse prognosis. This may be explained on the basis that gastric ulcer perforations are more likely to occur in older patients and are more likely to produce greater spillage of intragastric contents into the peritoneal cavity.

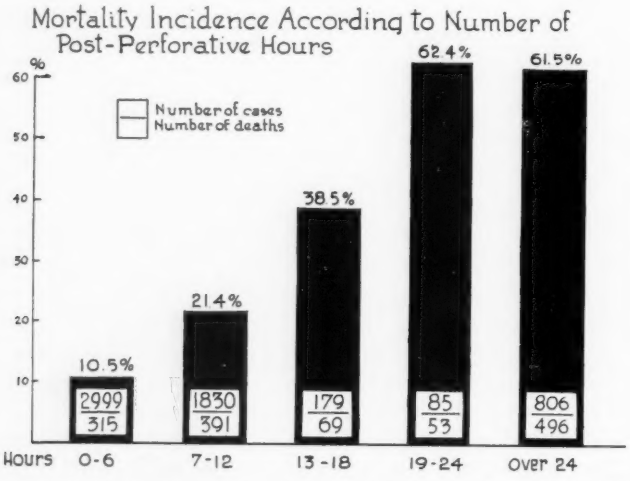


Graph XVI.—Mortality incidence in perforated gastroduodenal ulceration according to location in 4,825 collected cases.

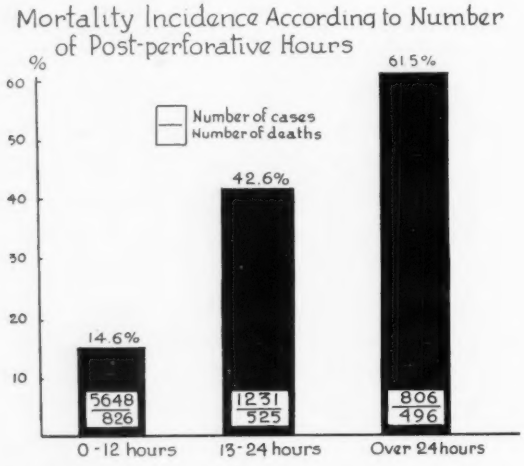
It has long been common knowledge that one of the most significant factors in the prognosis of perforated gastroduodenal ulceration is the time elapsing between the perforation and the operation. Numerous observers have directed attention to the fact that the mortality increases commensurably with the period elapsing between perforation and operation. In 1914 Collinson[116] reported a mortality incidence of 12.5 per cent in those patients operated upon during the first twelve hours after perforation and 58.6 per cent in those after twelve hours. A number of authors[45, 97, 351, 423, 458, 513, 614, 624, 626] have reported series ranging from 14 to 31 cases operated upon during the first six hours with no deaths. Others have reported much larger series with mortality incidences of less than 5 per cent in the first six-hour period[142, 219, 228, 252, 311, 403, 514, 519, 560, 568, 619] and less than 10 per cent in the first twelve-hour period.[83, 430, 657, 688] Bager[21] in an analysis of 1,495 cases found that the mortality was 14.7 per cent for the first six-

hour period, 26.5 per cent for the second six-hour period, 47.2 per cent for those operated upon between twelve and twenty-four hours after perforation, and 65.6 per cent for those operated upon after twenty-four hours. Shawan[593] found that the mortality rate in the second six-hour period was double that of the first and that in the second twelve-hour period it was more than three times the first. In the collected cases analyzed by Blackford and Baker[53] the mortality in the second twelve-hour period was approximately double that of the first and after the twenty-four-hour period it was more than four times as great. Somewhat similar results were obtained by Eliason and Ebeling[179] in their collected series. In his large series Judine[323] found a mortality incidence of 8.7 per cent in the first six-hour period and of 12.2 per cent in the second. Whereas, in those operated upon within twelve hours after perforation the mortality was 9.7 per cent, in those operated upon between twelve and twenty-four hours it was 26.9 per cent and after twenty-four hours 45.5 per cent. In the Charity Hospital series the mortality was 10.7 per cent during the first six hours, 15.1 per cent during the second, 26.3 per cent during the third, 37.5 per cent during the fourth, and 54.5 per cent in those operated upon after twenty-four hours.[147] In a series of 7,683 cases collected from the literature,[735] and including ours, it was found that the mortality incidence was 10.5 per cent in the first six-hour period, 21.4 per cent in the second, 38.5 per cent in the third, 62.4 per cent in the fourth, and 61.5 per cent after twenty-four hours (Graph XVII). Thus, during the first twelve-hour period after the perforation the mortality incidence was 14.6 per cent; during the second twelve-hour period, 42.6 per cent, an almost threefold increase; and after twenty-four hours it rose to 61.5 per cent (Graph XVIII). These statistics clearly demonstrate the significance of the interval elapsing between the onset of perforation and the operation and that, other things being equal, the longer this period the worse the prognosis. However, as emphasized by Graves[252] and Odom and myself[147] it should be realized that this time factor is not always the most important nor is the prognosis always commensurate with the delay interval. In the collected series reported by Graves the mortality incidence was 33 per cent in patients operated upon from forty-eight to seventy-two hours after perforation; whereas, in those operated upon between twenty-four and forty-eight hours after perforation it was 50 per cent. A somewhat similar observation was made by Thompson,[641] who found that, although the mortality was 46.2 per cent in those cases operated upon between thirteen and twenty-four hours after perforation, it was 34.2 per cent in those operated upon twenty-four hours or more after perforation. Obviously, there are other significant qualifying factors in addition to the delay interval. Graves[252] directed attention to the fact that the general condition of the

patient and the amount of peritoneal contamination that has occurred also play significant roles. A perforation that has occurred forty-eight hours previous to operation may become walled off or plugged by adhesions immediately after the occurrence of the perforation, resulting in a relatively small amount of peritoneal contamination. Obviously,



Graph XVII.—Mortality incidence in perforated gastroduodenal ulceration according to time elapsing between perforation and operation.

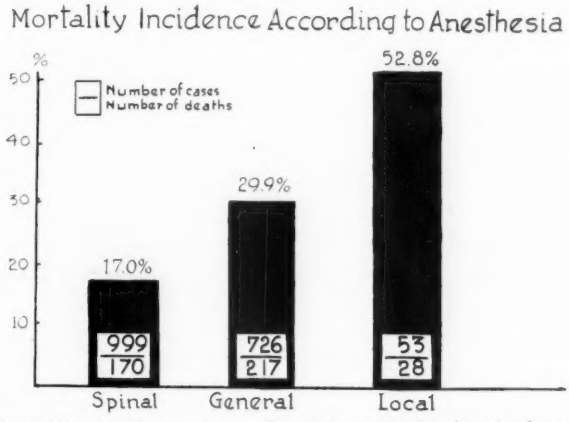


Graph XVIII.—Mortality incidence in perforated gastroduodenal ulceration according to time elapsing between the perforation and operation. It may be observed that the mortality during the second twelve-hour period is approximately three times that of the first twelve-hour period, and after twenty-four hours is over four times that during the first twelve-hour period.

such a patient is less likely to develop a generalized peritonitis than one whose perforation remains open even though he is operated upon within twelve or twenty-four hours after the perforation.

The type of anesthetic employed in operations for perforation of gastroduodenal ulceration is a significant prognostic factor. A review of the literature indicates some controversy regarding the anesthetic

of choice. Although in the past most authors preferred general anesthesia, more recently the majority of observers consider spinal analgesia the most desirable. For the sake of expediency the anesthesias may be classified into three groups: (1) general anesthesia, (2) spinal analgesia, and (3) local analgesia. Sallick[560] found a mortality incidence of 6 per cent in those cases operated upon under general anesthesia and 17.4 per cent in those under spinal. A lower mortality in the former group was also observed by McCleery,[399] although they were admittedly better risk cases. Whereas, Eliason and Ebeling[179] had a higher mortality in the general anesthesia group, they concluded that this was the anesthetic of choice. Bizard and Malatray,[50] Pototschnig,[523] and Trout[654] have also indicated their preference for general anesthesia. On the other hand, numerous others[14, 109, 287, 309, 430, 512, 682] have definitely concluded that spinal analgesia was the most desirable. Corff[122] reported mortality incidence of 26.6 per cent for the general



Graph XIX.—Mortality incidence in perforated gastroduodenal ulceration according to type of anesthetic employed.

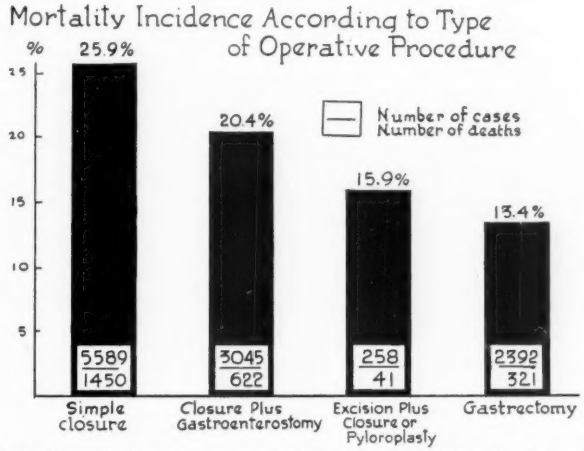
anesthesia group, 18.8 per cent for the spinal, and 71.4 per cent for the local. An even greater contrast was observed by Fallis,[192] who found these corresponding incidences to be 29.3, 7.3, and 100 per cent. In relatively large series Shawan[593] and Judine[323] found that the mortality rates in the cases operated upon under general anesthesia were twice and four times, respectively, those under spinal analgesia. In the Charity Hospital series[147] the mortality incidence in 43 cases operated upon under general anesthesia was 23.2 per cent; in 161 cases under spinal, 15.5 per cent; and in 5 cases under local, 60 per cent. In a series of 1,776 cases collected from the literature[736] the mortality incidence in the general anesthesia group was 29.9 per cent, in the spinal 17 per cent, and in the local 52.8 per cent (Graph XIX). From these statistics it would appear that spinal analgesia offers a better prognosis. It is probable that the higher mortality rate in the local analgesia group is due to the fact that it comprised cases that were

originally poor risks. Morley[430] states that he prefers spinal analgesia to general anesthesia because the extreme respiratory effort associated with the latter produces a plunging action of liver through movements of the diaphragm and consequent dissemination of intragastroduodenal contents in the peritoneal cavity. In a previous publication I[147] expressed the opinion that spinal analgesia is preferable because complete relaxation is obtained, permitting better exposure and less manipulative trauma. Moreover, such relaxation is difficult to effect in these cases with general anesthesia because of the peritoneal irritation, and the toxicity of a general anesthetic is an additional burden upon the liver. However, spinal analgesia should be administered by an experienced anesthetist whose careful observation of the patient is continued during the entire procedure.

That the type of operative procedure employed in perforated gastroduodenal ulceration is a significant factor in the prognosis is clearly revealed by the numerous reported statistics of various authors. However, there still rages considerable controversy regarding the choice of the different types of procedures that have been advocated. In general the majority of American and English surgeons favor the more conservative procedure of simple closure; whereas, the continental European surgeons are warm advocates of the more radical procedure of partial gastrectomy. The advantages and disadvantages that have been advocated will be considered later. Of interest here, whowever, is the influence of these procedures upon prognosis and mortality.

A number of authors advocating the more conservative procedure of simple closure have reported mortality incidences following such procedures of less than 15 per cent. On the other hand, many others favoring the more radical procedure of partial gastrectomy have reported even lower mortality incidences. The low mortality rates of less than 2 per cent reported by Graham,[248] Pich,[513] and Tilton[643] following simple closure are unusual. However, Nicolas[458] had a mortality incidence following such a procedure of only 3.6 per cent; Gilmour and Saint,[243] 4.7 per cent; and Black,[51] 5.4 per cent. Hagyard[267] reported 78 cases operated upon by this more conservative procedure with a mortality incidence of only 6.4 per cent. Sallick[560] had 74 cases with a mortality rate of 10.8 per cent. Bryce,[87] Shelley,[594] and Woodall[704] each reported incidences of about 13 per cent. On the other hand, a number of authors have reported comparative statistics from their clinics which reveal lower mortality incidences following the more radical procedures. Bager[21] in an unusually large series of cases found that the mortality rate following simple closure was 32.8 per cent; following closure plus gastroenterostomy, 23.4 per cent; and following partial gastrectomy, 25 per cent. Even greater contrasts were observed by Baron,[32] Gerhardt,[238] and Judine.[323] Baron[32] found that the mortality incidence following simple closure was 42.1 per

cent; whereas, that following partial gastrectomy was only 18.8 per cent. The respective incidences in Gerhardt's[238] series were 64.7 and 17.9 per cent and in Judine's[323] large series they were 42.7 and 8.9 per cent. Graves[252] also observed in a collected series of 775 cases that gastric resection was followed by a lower mortality than the more conservative procedures. In a collected series of 11,284 cases[732] the mortality following simple closure was 25.9 per cent; following closure plus gastroenterostomy, 20.4 per cent; following excision plus closure or pyloroplasty, 15.9 per cent; and following partial gastrectomy, 13.4 per cent (Graph XX). Thus from these statistics it would appear that the more radical procedures offer a better prognosis. Indeed the most conservative procedure, simple closure, resulted in a higher death rate than the general mortality. However, it should be realized that a large number of the cases, particularly in the continental European clinics, in which simple closure was performed were admittedly the

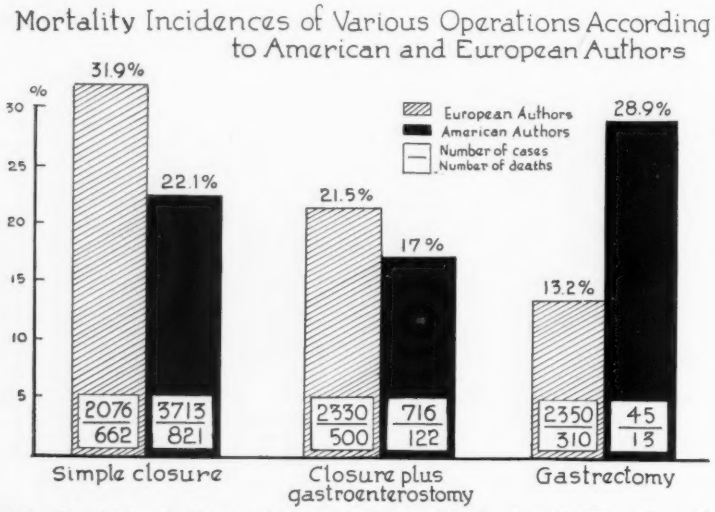


Graph XX.—Mortality incidence in perforated gastroduodenal ulceration according to type of operative procedure employed.

poor risks. Moreover, as emphasized previously, the more radical procedure of partial gastrectomy is an operation which is performed relatively frequently and therefore skillfully in these clinics. The significance of these factors in evaluating these statistics is clearly demonstrated by the fact that the mortality incidences in the collected series of the continental European clinics following simple closure was 31.9 per cent; whereas, in the American and English clinics it was 22.1 per cent. On the other hand, the former authors had an incidence of only 13.2 per cent following partial gastrectomy as compared with 28.9 per cent in the hands of the latter (Graph XXI). Obviously, the only conclusion that can be drawn from these statistical analyses is that comparative mortality rates for the various type of operative procedures cannot determine the superiority of one over the other. The author who has chosen a certain procedure as the one of choice will stress its value and rarely consider other factors which are in

many instances even more significant. Thus the various factors previously mentioned the general condition of the patient, the pre- and postoperative management, and the relative technical skill of the surgeon are all factors which should be considered in evaluating such statistical analyses.

The significance of complications as a factor in the prognosis is well known. Turner[658] found that, whereas the mortality incidence in the noncomplicated cases was 11.3 per cent, in those with complications it was 39.1 per cent. Similarly McCreery[403] states that these corresponding figures were 17.3 and 32.4 per cent. The two most frequent complications, peritonitis and pulmonary affections, comprise the most common causes of death. Of the 31 deaths in the series reported by Dineen,[154] 29 (93.5 per cent) were due to these complications. Fleming[214] found in a collected series of 253 fatal cases that peritonitis

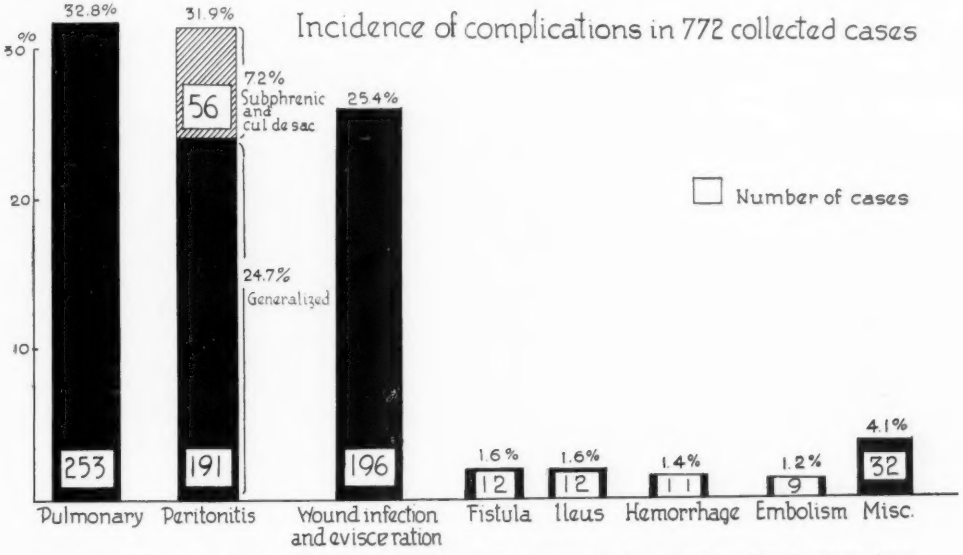


Graph XXI.—Mortality incidence in perforated gastroduodenal ulceration of various operative procedures according to American and European authors.

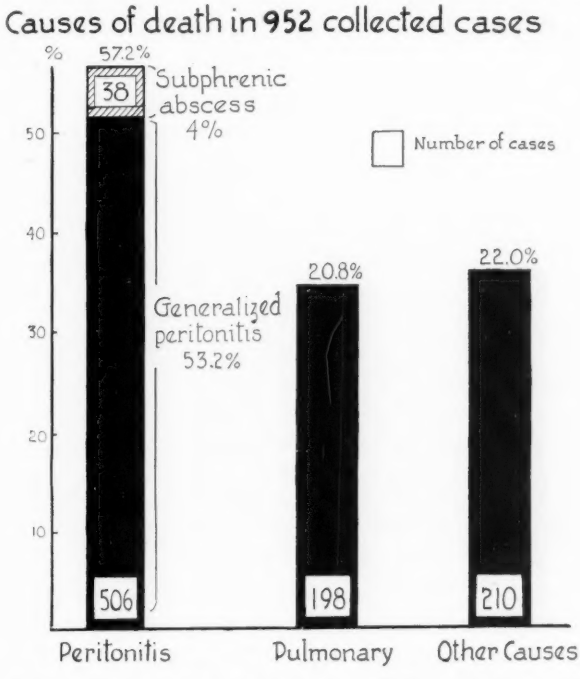
accounted for the fatalities in 65 per cent and pulmonary affections in 13 per cent. In a series of 672 collected cases Eliason and Ebeling[179] also found that these complications were the causes of death in 59 and 15.3 per cent respectively.

The significance of the various complications is demonstrated further by their respective incidences and their frequency in the causes of death. Thus in a collected series of 772 complications[737] peritonitis comprised 31.9 per cent and pulmonary affections 32.8 per cent (Graph XXII). In a collected series of 952 causes of death[738] peritonitis was found in 57.2 per cent and pulmonary affections in 20.8 per cent (Graph XXIII). Thus the seriousness of these two complications is clearly revealed by the fact that they comprised over 60 per cent of all complications and over three-fourths of the causes of deaths.

Of the 247 cases of peritonitis in the collected series of complications 191 were generalized and 56 were localized. Of the latter 43 were subphrenic abscesses and 13 were cul-de-sac abscesses. In a previous publication Ochsner and I[472] found that in a collected series of 3,533 cases of subphrenic abscess the origin was from perforated lesions of the stomach and duodenum in 28.7 per cent. The next most frequent com-

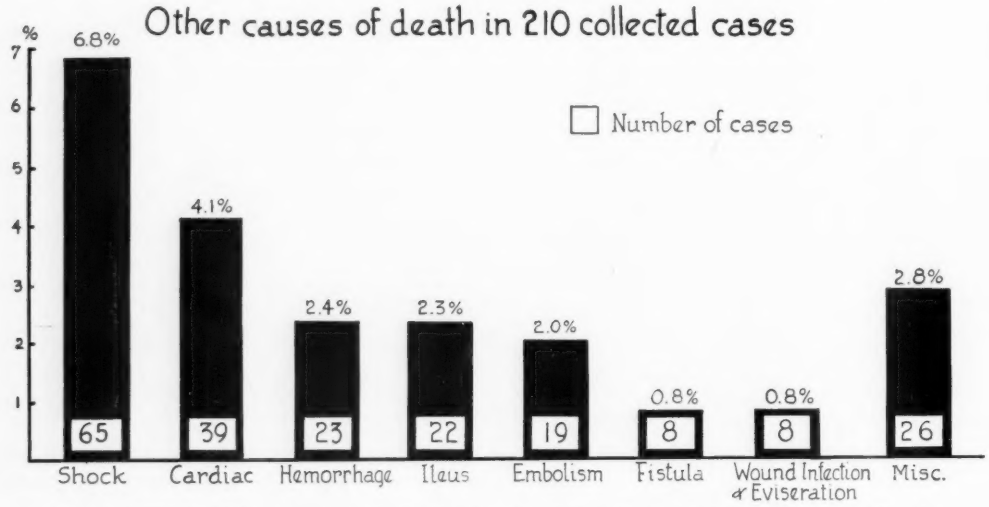


Graph XXII.—Incidence of complications in perforated gastroduodenal ulceration.



Graph XXIII.—Incidence of causes of death in perforated gastroduodenal ulceration.

plication, wound infections and evisceration, formed 25.4 per cent of the complications but only slightly less than 1 per cent of the causes of death (Graphs XXII and XXIV). Gastroduodenal fistulas comprised 1.6 per cent of the complications and less than 1 per cent of the causes of death (Graphs XXII and XXIV). Pulmonary embolism occurred in 1.2 per cent of the complications and 2 per cent of the causes of death (Graphs XXII and XXIV). In the Charity Hospital series of 211 cases wound infections and evisceration occurred as complications in 28.9 per cent, peritonitis in 19.8 per cent, pulmonary affections in 11.3 per cent, ileus in 2.3 per cent, and hemorrhage in 1.4 per cent. The relative importance of these complications may be determined by



Graph XXIV.—Other causes of deaths in the 210 collected cases shown in Graph XXIII.

their incidence of deaths. Thus, of those having wound infections 13.1 per cent died, of those having pulmonary affections 70.8 per cent died, of those with peritonitis 71.4 per cent died, of those with ileus 80 per cent died, and of those with hemorrhage 100 per cent died.

Recurrence.—According to available statistics recurrent perforation occurs relatively infrequently, although numerous cases have been reported.[739] In 1923 McKnight[407] reported a case in which perforations occurred on three different occasions. Similar cases have since been reported by others.[175, 284, 383] Nixon and Lowry[461] and Lysoght and Williams[375] have each recorded cases in which perforations occurred in the same patient on four different occasions. Of even greater interest is the case reported by Henry[281] in which five perforations occurred during a period of four years. Similarly Davenport[137] observed a case with five perforations occurring over a period of twelve years. Gosset and co-workers[245] recently collected 64 cases from the literature. In 1925 Turner[658] reported 1 case with previous perforation in

a series of 147, an incidence of 0.7 per cent. Platou[516] found 3 (5 per cent) cases in a series of 60 and Searby[584] observed 4 (2.7 per cent) in a series of 146. Shelley[594] and Read[540] had incidences of 3.7 per cent and 4 per cent respectively. In a series of 211 cases reported by Odom and myself[147] this incidence was 0.5 per cent. In 1932 Pearse[499] attempted to determine the incidence of recurrent perforation on the basis of collected cases. Accordingly in a series of 4,183 cases of perforated peptic ulcer 33 (0.69 per cent) instances of reperforation were found. I have collected 6,538 cases[740] and of this number there were 74 (1.1 per cent) reperforations.

Obviously, it is frequently difficult to determine whether the reperforation has occurred at the exact site of the previous perforation. In some of the reported cases this has been determined by the presence of nonabsorbable suture material. In others it has also been possible to state definitely that the reperforation was in a different location.

Of particular interest is the influence of the type of procedure previously performed upon the incidence of reperforation. In the collected cases reported by Pearse[499] it was found that the incidence of reperforation after the various surgical procedures approximated the respective incidences of their use. Whereas only 1 of 24 reperforations following simple closure had more than two perforations, of 8 following simple closure plus gastroenterostomy 5 reperforated three or four times.

Treatment.—Although cases of perforated gastroduodenal ulceration with spontaneous recovery have been reported,[3, 211, 336, 352, 450, 601, 689] it is the general consensus that the treatment is surgical. However, the type of surgical procedure which should be performed remains yet a controversial issue. The procedures most widely employed are simple closure, closure plus gastroenterostomy, excision and pyloroplasty, and partial gastric resection. Gastrostomy is occasionally used, but tamponade[9, 44, 295] is rarely advocated.

Gastrostomy.—The procedure of gastrostomy either by fixation of the perforated area of stomach to the abdominal wall or by means of a rubber tube has been advocated by some authors. Neumann[456] in 1909 originally suggested the technique of inserting a rubber tube into the stomach through the perforation and fixing it to the wall of the stomach with sutures. The omentum is then placed around the tube which is brought through the wound to the outside. About the tenth postoperative day the tube is removed and the fistula allowed to close. The procedure is considered advantageous in those cases of perforation in which the tissues surrounding the perforation are so inflamed, indurated, and friable that simple closure is difficult to effect. Although this procedure is rarely employed today, there are

some authors who still advocate it and even consider it the method of choice.[70, 326, 352, 571] Others are of the opinion that there are occasional indications for its use.[458, 658, 694] Turner[658] reported in a series of 147 cases 26 cases in which he believed it indicated. More recently Williams and Walsh[694] have suggested a slight modification of the Neumann method. They employ a double tube, one within the other. The outer tube has several perforations for a distance of 1½ inches from the tip. The inner tube consists of a ureteric catheter which is passed through the outer tube and projects for several inches beyond the gip of the latter. After placing the double tube through the stomach wall, it is so adjusted that the perforated part of the outer tube lies in the stomach and the inner tube in the duodenum. Thus the tubes serves a dual purpose of draining the stomach and introducing fluid into the duodenum.

Simple Closure.—The technique of simple closure originally performed by Mikulicz[419] on Nov. 7, 1880, is probably the oldest method employed for the surgical treatment of acute perforated gastroduodenal ulceration. Moreover, it probably still enjoys the widest popularity. Whereas in general the procedure consists of simple repair of the defect, considerable variations in its actual performance have been suggested. Some surgeons merely use a purse-string suture followed by a few Lembert inverting or reinforcing sutures. Others employ only interrupted sutures placing them in the longitudinal axis with the first row inserted through the entire wall at the margins followed by a second row of inverting sutures. Some prefer catgut; whereas, others use this material only for the first row and silk or some other nonabsorbable suture material for the second row.

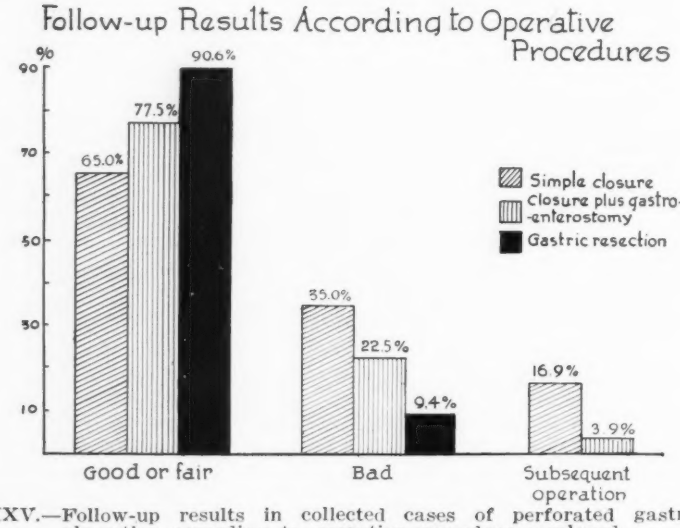
The use of an omental graft over the closure has been advocated by some. Bennett[40] in 1896 and Braun[68] and Mickulicz[419] in 1897 suggested the use of an omental plug to close the perforation in those cases in which closure could not be effected adequately by simple suture because of the surrounding induration. Cellan-Jones[103] in 1929 described a method of closure which consists of placing four to six catgut sutures through the stomach wall at the margins of the perforation, so as to form an "archway of sutures." An omental strand is then brought through this archway of sutures and the sutures tied over the omentum. A somewhat similar procedure has been described more recently by Graham.[248] According to these authors the advantage of such a procedure is that it can be simply and quickly performed with a minimum degree of trauma. Moreover, adequate closure of the defect is readily done even in cases in which there is considerable induration surrounding the perforation and the danger of constriction is minimized.

The procedure recently described by Gatch and Owen[231] consists of placing several interrupted silk sutures through the stomach wall one or two inches proximal to the perforation and a similar distance on the duodenum distal to the ulcer. When the sutures are tied, the anterior surface of the stomach is pulled over the perforation and is attached to the duodenal wall. Of 26 cases treated in this manner 5 died. Of those that recovered only 1 required subsequent operation. Others[46, 162] have suggested the use of the gall bladder to close over the perforation.

Great controversy has long ranged between the advocates of simple closure and those who favor additional procedures. The former have maintained (1) that acute perforated gastroduodenal ulceration is a surgical emergency and the procedure of choice under such circumstances is one which effects adequate repair in the quickest and simplest manner; (2) that morbidity and operative mortality are decreased; (3) that prompt healing of the ulcer occurs and in the majority of cases is permanent; (4) that the danger of subsequent constriction and obstruction is infrequent and even if it occurs subsequent operation may be performed under more ideal conditions; (5) that the performance of an additional procedure not only is usually unnecessary and subjects the patient to unjustifiable risk but also frequently does not prevent the development of complications, such as recurrence of the ulcer and perforation, hemorrhage, and new ulceration.

Numerous surgeons with wide experience have concluded that simple closure is the procedure of choice and in support of the contentions enumerated above have advanced carefully evaluated results of operation. In 1912 Eliot and co-workers[183] in an extensive critical analysis of this subject came to the conclusion that the omission of an additional procedure was not responsible for a single fatality. Similar conclusions were reached by the group of Edinburgh surgeons[96] and by Collinson.[116] Moreover, it has been clearly demonstrated by subsequent exploration that the ulcer heals satisfactorily following simple closure.[36, 71, 356, 486] Clinically, it has been shown by follow-up studies that additional procedures are unnecessary in the majority of cases. Thus, Engelsing[186] and Brown[83] found their results very satisfactory and Gibson,[242] who has studied this subject intensively, found that of 93 cases treated by simple closure approximately one-half were symptom free and only 21 required subsequent operation. In Farr's[194] series of 21 cases 19 remained free of complaints. Similarly, Southam[619] found that 90 per cent of 37 cases required no further treatment. In Garlock's[228] series of 69 cases only 14 necessitated subsequent operation and 63.9 per cent of Urrutia's[661] cases remained well. Of Dineen's[154] 95 cases only 18 continued to have complaints. Radoievitch[530] in an analysis of follow-up results of a collected series of 353

cases treated by simple closure found that good results were obtained in 58 per cent, fair in 7.9 per cent, and bad in 33.9 per cent. Similarly Johnston[315] analyzed a collected series of 364 cases and found that 69 per cent remained perfectly well and only 24.8 per cent had more or less severe symptoms. White and Patterson[688] estimated that approximately 60 to 65 per cent of patients treated by simple closure will remain free of symptoms and only 10 to 15 per cent will require further surgery. Of the latter group 49 (10.7 per cent) cases required subsequent operation. In a collected series of 1,525 cases[741] it was found that over one-half remained symptom free, 35 per cent continued to complain, and only 16.9 per cent required subsequent operation (Graph XXV). Thus from these statistics it may be observed that the majority of patients treated by simple closure remain perfectly well and only a relatively small number require further surgical intervention.



Graph XXV.—Follow-up results in collected cases of perforated gastroduodenal ulceration according to operative procedure employed.

There has been a definite trend toward the more conservative procedures of simple closure. Guthrie[263] in 1923 sent out a questionnaire to prominent abdominal surgeons in this country and of 152 replies it was found that the majority favored the more conservative procedure. Since then numerous others have expressed similar opinions.[742] Graham[248] states that additional procedures are "meddlesome and unnecessary." Troutt,[654] who has long been interested in this subject, is also of the opinion that simple closure is the more desirable procedure and states that the "sooner we surgeons realize that surgery can only be an aid, though often a most important one, in the treatment of "peptic" ulcers, the better such an attitude will be for the ultimate satisfactory condition of our patients." With this opinion the author thoroughly concurs.

Simple Closure Plus Gastroenterostomy.—The procedure of closure of the perforation plus gastroenterostomy in the treatment of acute perforated gastroduodenal ulceration was originally performed by Braun[68] and Hartmann and Soupault[274a] in 1897 and suggested by Moynihan[435] in 1901. Whereas numerous surgeons have since advocated the addition of gastroenterostomy as a routine procedure in the treatment of these cases, it should be realized that Moynihan[435] recommended its use in those cases in which "it was obvious that the duodenum at the point of ulceration was so narrowed by the suturing that a marked structure of the bowel would inevitably result." It would appear that Moynihan's qualified recommendation was misinterpreted and a number of surgeons who began performing this procedure subsequently believed that it had sufficient advantages to warrant its routine use. This led to the controversy that still rages between those who consider the more conservative procedure of simple closure the most desirable and those who are warm advocates of closure plus gastroenterostomy. The latter group have maintained that the advantages of the additional procedure of gastroenterostomy are that (1) healing of the perforated ulcer is enhanced by diminishing tension on the suture line; (2) in many cases closure of the perforation cannot be adequately effected without producing obstruction to the lumen; (3) the danger of perforation and hemorrhage from coexisting ulcers is diminished; (4) the immediate mortality is not increased; (5) it permits earlier nutrition; (6) it obviates the necessity of subsequent operation which will be necessary in many patients treated by simple closure; and (7) the late results are very much better. Whereas it would appear from these advantages that the routine use of the procedure is certainly justified, a critical analysis reveals that there are many objections. Eliot and co-workers[183] in a careful survey of this subject grouped the arguments advanced by many observers against gastroenterostomy as follows: "(A) it prolongs an operation which is one of emergency and which it is always desirable to conclude in the shortest possible time; (B) that it subjects the patient to the added risk of infection of the lesser peritoneal cavity; (C) that patients in whom a gastroenterostomy is done are not always relieved of their gastric symptoms; (D) that patients treated by suture only frequently suffer from no recurrence of their symptoms; (E) that in those cases of perforation treated by suture only, in which the symptoms of gastric ulcer either persist or recur, a gastroenterostomy can be done more safely at the time of perforation; (F) that patients in whom a gastroenterostomy is added to the closure of a perforation are subjected to the risk of a subsequent peptic ulcer in the jejunum."

Collinson[116] in a similar consideration of this subject aptly summed up the entire problem in two questions: "(1) Is a gastroenterostomy

necessary or advisable for the immediate recovery of the patient? (2) Is it advisable in order to obviate future trouble provided he recovers from the perforation?'' In answer to the first question he concluded that there is apparently little or no difference in the immediate convalescence between the two procedures.

The argument that gastroenterostomy relieves the tension on the suture line and consequently enhances healing is open to objection. Eliot and associates[183] state that ''this accident rarely if ever occurs.'' The Edinburgh group[96] and Collinson[116] also concluded that ''this was no evidence to show that in a single case'' the omission of gastroenterostomy was responsible for a fatal result. Moreover, with the present universal use of intranasal gastroduodenal suction such an argument is no longer tenable.

The advantage of gastroenterostomy advanced by its advocates that it obviates pyloric obstruction frequently resulting from simple closure has been greatly exaggerated. Eliot[183] is convinced that ''such a contingency is very unusual.'' Similar opinions have been expressed by others.[242, 619] It has been demonstrated experimentally that permanent constriction of the bowel is extremely difficult to produce even when as much as two-thirds of the circumference has been excised.[183, 376] Cautery puncture of the duodenum near the pylorus followed by practical occlusion of the lumen consequent to suture and infolding was performed in dogs by Stewart and Barber.[626] The results of this procedure failed to produce permanent pyloric obstruction. On the basis of these clinical and experimental observations it would appear that gastroenterostomy is rarely necessary to obviate the subsequent occurrence of pyloric obstruction by constriction.

That the danger of subsequent perforation and hemorrhage is diminished by the additional gastroenterostomy is questionable. In considering this argument Eliot[183] collected 3 cases in which perforation of coexisting ulcers occurred within one month after the performance of suture plus gastroenterostomy and 15 remote perforations after this procedure had been done. Numerous others[13, 223, 339, 599, 651, 694] have since reported reperforations in cases with gastroenterostomy. Eliot[183] was also able to collect 3 cases of hemorrhage from coexisting ulcers after this operation had been done.

The favorable or unfavorable effect of added gastroenterostomy upon the immediate mortality is difficult to establish. The advocates of one or the other procedure can easily present mortality statistics in support of their respective views. Obviously as previously emphasized such an argument fails to take in consideration the various other factors which are probably more important in influencing mortality statistics. This was clearly emphasized by Cope,[119] who justifiably protested against the presentation of mortality statistics as proof of

the superiority of closure plus gastroenterostomy. Williams and Walsh[694] also directed attention to the fact that such statistics are not comparable. Whereas closure plus gastrojejunostomy is generally performed in selective cases, simple closure is commonly reserved for poor operative risks. Moreover, such factors as age, type and size of the perforation, delay interval, anesthesia, and relative technical ability must also be considered in the evaluation of such statistics.

That added gastroenterostomy produced better late results has been one of the most important advantages presented by the advocates of this procedure. Deaver[140] has long been a champion of primary gastrojejunostomy and in a more recent publication[142] reported 17 cases that were permanently cured. Schilling[568] reported 85 per cent of his patients had satisfactory follow-up records. Semb[588] found that only 4 of 68 cases had recurrent severe symptoms. In a collected series of 169 cases Radoievitch[530] found that 94 per cent were permanently relieved and only 3.5 per cent had poor results. In Johnston's[315] collected series 78.4 per cent had favorable courses and 21.6 per cent had recurrent symptoms three of which were subsequently operated upon for gastro-jejunal ulcers. Of the 325 cases reported by Bager[21] 68 per cent had good results and 19.1 per cent had recurrent manifestations of which 5.2 per cent required subsequent operation. Ramb[531] found the results were bad in 50 per cent. In considering the late results of gastroenterostomy or partial gastrectomy for ulcer, Hurst[304] found that poor results were obtained in 67 per cent. In a collective investigation of a large series of cases of the after-history of gastroenterostomy Luff[372, 373] found that unsatisfactory results were obtained in 23 per cent of the gastric and 11 per cent of the duodenal ulcers. In a series of 764 cases collected from the more recent literature[743] 67 per cent were reported as being permanently relieved, 10.5 per cent as having slight and 22.5 per cent as having severe recurrent symptoms. Approximately 4 per cent required subsequent operation (Graph XXV).

From these statistics it is obvious that added gastroenterostomy does not prevent the development of recurrent manifestations of ulceration in a relatively high percentage of cases.

Moreover, the danger of the development of anastomotic jejunal ulcers following this procedure deserves serious consideration. Lewisohn,[363] who was an early advocate of primary anastomosis, has more recently[365] expressed an antithetical opinion. He found that gastrojejunal ulcers occurred in 34 per cent of these cases. The incidence of gastrojejunal ulcers following the procedure of gastrojejunostomy varies according to the reported statistics and depends upon the care and thoroughness of the follow-up studies. Braun[69] in 1899 originally reported the occurrence of this complication and of interest is the fact that it was perforated. Ten years later Paterson[492]

stated that he was able to collect 52 cases. According to available statistics the incidence of this complication varies from the low figure of 1 to 2 per cent to as high as 66 per cent.[744] Graham and Lewis[249] believe it occurs with sufficient frequency to bear a real significance. On the basis of his statistical survey that of 31 gastroenterostomies performed for benign lesions 48.3 per cent developed jejunal ulcers and a study of the experience of others, Newburger[457] emphatically condemns the procedure. The increased susceptibility of the jejunal mucosa to ulceration has been repeatedly demonstrated experimentally. A number of investigators[273, 386, 395, 408] have definitely shown that there is a commensurable susceptibility of the intestinal tract to acid gastric peptic activity as the distance from the pylorus is aborally increased. In experiments previously presented I[143, 145] found that jejunal ulcers developed in 50 per cent of dogs in which pyloric occlusion and gastrojejunostomy were performed. It is believed that the best possible explanation for this high incidence "is that the jejunal mucosa is functionally unable to receive acid gastric chyme, and this factor is relatively more pronounced after this procedure as the pyloric occlusion does not permit a regurgitation of the alkaline duodenal juices into the stomach to help neutralize the gastric acidity." On the basis of clinical observations and experimental investigations performed in the Tulane Surgical Laboratory, Ochsner, Gage, and I[143-145, 147, 226, 466, 467, 470, 471] are firmly convinced that gastrojejunostomy should rarely, if ever, be employed in patients whose gastric acidity is normal or above normal. Graham[248] has shown that the average incidence of free hydrochloric acid in 25 cases of perforated gastroduodenal ulceration was 50 clinical unity. It is my opinion that the majority of these cases have either a normal or hyperacidity of gastric secretions.

In addition to the increased risk of recurrent ulcer manifestations following this procedure there is the danger of perforation of the jejunal ulcer. Massie[392] and Singer and Meyer[605] have reported the occurrence of this complication and in a recent publication Toland and Thompson[645] reported 10 new cases and collected 93 cases from the literature. The most common complication of the primary pathology for which the gastrojejunostomy was originally performed was acute perforation.

Excision and Pyloroplasty.—The procedure of excision of the ulcer followed by some type of pyloroplasty was introduced by Dowden[160] in 1909. Since then a number of surgeons[745] have advocated the procedure although it has never received great popularity. The advocates of this procedure have maintained that its advantages are: (1) that the lesion is removed, (2) that pyloric stenosis is avoided, thus obviating the necessity of the "unphysiologic" procedure of gastroenterostomy, (3) that the time of operation is increased very

slightly over simple, (4) that the usual location of the ulcer lends itself readily to the performance of the procedure, and (5) that by excision of the infected, indurated ulcer margin, healing of normal tissue is permitted. Dunbar[168] considers it the procedure of choice and states that he has obtained excellent results. Grimault[257] reports 10 cases followed for over 10 years who remained well. Moynihan[441] believes the procedure is indicated in those cases in which the ulcer is situated at or just proximal to the pylorus. Donald[158] believes the procedure has a "definite place" in the treatment of perforated duodenal ulcers. Johnston[315] found that 23.8 per cent reported more or less severe symptoms following this procedure. Rowlands and Turner[555] found good results in only 7 of 12 cases. In view of his poor results following this procedure Hinton[290] concluded its continued use was unjustified.

Partial Gastrectomy.—The procedure of subtotal gastric resection was advocated originally by von Haberer[265] in 1919 but was performed previously by Keetly[327] in 1902 and subsequently by several others.[190, 300, 391, 496, 580, 710] However, it was not until after von Haberer's publication that the procedure became more extensively used. At the present time this type of operative treatment is enjoying its greatest popularity among continental European surgeons.[746] The advocates of this method of therapy contend that the immediate mortality is not increased, that a large number of patients treated by the more conservative procedure will require further surgical intervention, and that the procedure is more rational because its aim is curative rather than palliative. Whereas many advocates recommend its use almost routinely, the majority consider it desirable to limit its use to the better risk cases in which operation can be performed within a relatively short time after operation.

There is no doubt that according to the reported statistics the immediate mortality following partial gastric resection is not increased. Amazingly enough it seems to be actually decreased. Odelberg[473] and Mülledger and Neuberger[444] had only 1 death each in series of 20 and 21 cases respectively. Judine[323] in an unusually large personal series of 937 cases reports the astonishingly low mortality of 8.9 per cent. It will also be recalled that in the collected series above the mortality incidence was lowest for the gastric resection cases. However, as previously emphasized such statistics are not comparable and should not be used to demonstrate the superiority of a procedure. There are many other factors of probably greater importance that must be considered in the evaluation of these statistics. However, the low mortality incidences of these authors show that such a radical procedure can be performed in the better risk cases by surgeons well experienced in this field of endeavor with no greater immediate danger.

The follow-up results reported by various authors following gastric resection reveal a higher incidence of permanent cures than by other procedures. Bager[21] in a series of 41 cases found good results in 56 per cent, and more or less severe recurrent symptoms in 43 per cent. In his series of 85 cases Judine[323] reported permanent relief of symptoms in 76.4 per cent. Gerhardt[238] and Koehl[337] reported over 93 per cent permanent cures in a series of 32 cases and 16 cases respectively. In a collected series of 385[747] good results were obtained in 81.8 per cent, fair in 8.8 per cent, and poor in 9.4 per cent (Graph XXV).

Thus it would appear from these statistics that approximately 80 per cent of patients having partial gastric resection are permanently relieved and about 20 per cent will have more or less severe recurrences. Of interest in this connection is the comparison of these figures with the results obtained by simple closure and closure plus gastroenterostomy. These respective incidences following simple closure were 52 and 48 per cent and following closure plus gastroenterostomy, 67 and 33 per cent. Thus the more formidable procedure of gastric resection diminishes the incidence of recurrence only 13 and 28 per cent over closure plus gastroenterostomy and simple closure respectively (Graph XXV). Moreover, one-fifth of the cases will still not be relieved. In view of these observations and the fact that the procedure is admittedly one that should be performed only by a surgeon well experienced in gastric surgery, it seems to me that partial resection has a very limited applicability in the treatment of acute perforated gastric-duodenal ulceration.

Drainage.—Considerable controversy still exists regarding the advisability of instituting drainage in these cases. On the one hand, a large number of surgeons[748] advocate the routine employment of drainage, claiming that it is indicated because peritoneal contamination almost invariably occurs. On the other hand, an equal number[749] have maintained that drainage is of no value in preventing complications and in some cases is even hazardous. Between these two views are those[750] who believe that drainage should not be used in the early cases but that it should be employed in the late cases. Many continue to advocate suprapubic drainage. Obviously attempts to determine the relative value of drainage by statistical analysis of mortality and morbidity incidences are fallacious. There are too many other factors which must be considered in such an evaluation.

In 1923 Guthrie[263] found in response to his questionnaire that almost three-fourths of 137 surgeons routinely employ drainage. More recently it is my impression that there is a distinct trend toward omission of drainage. In 1935 Trout[652] found that in response to replies from more than 100 surgeons about 80 per cent do not use drainage as a rule. Finney[205] states drainage of the peritoneal cavity is not

used. White and Patterson[688] and McCreery[403] believe that drainage is rarely indicated. Epshteyn[188] and Graham[248] have discontinued its use in recent years. Graham who previously believed that drainage was an asset more recently stated that routine drainage is not only of doubtful value but even hazardous. Judine[323] considers drainage as "absolutely useless." Similar opinions have been expressed by numerous others. The possible harmful effects of suprapubic drainage have been emphasized by Bizard and Malatray[50] and Creyssel and de-Mourgues.[128] These authors observed fatal cases of intestinal obstruction resulting from such drainage. Trout[653] and Shipley[596] have recently emphasized the inadvisability of drainage. In a previous publication[474] it was stated that "for reasons which are not apparent, the question of drainage of the peritoneal cavity still seems to be controversial in the literature. It has been conclusively demonstrated that it is impossible to drain the peritoneal cavity in the case of generalized peritonitis. No matter what type of drain is employed, within eight to ten hours after it is placed in the peritoneal cavity it becomes completely walled off by fibrinous adhesions and all that is accomplished is drainage of the area in which the drain is situated. Consequently it seems irrational to place drains in the peritoneal cavity of patients with perforated ulcer in whom general peritonitis has developed. Equally irrational is the drainage of those persons operated upon before the peritonitis has become manifest, because, if contamination of the peritoneal cavity has occurred, the drains can serve no useful purpose. On the basis of these fundamental principles we do not advocate drainage except in those patients in whom residual peritoneal abscesses develop. However, drainage of the abdominal wall should always be done because contamination of the wound almost invariably occurs. Thin strips of soft rubber dam should be used and should be placed down to the transversalis fascia and peritoneum, because if the drain is placed only in the subcutaneous tissue, the possibility of an abscess developing in the abdominal wound between the rectus muscle and the posterior rectus sheath may be overlooked. As emphasized by Ochsner,[468] the danger of this possibility lies in the fact that the abscess may rupture into the peritoneal cavity rather than to the outside.

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Book Reviews

The Pineal Organ: The Comparative Anatomy of Median and Lateral Eyes, With Special Reference to the Origin of the Pineal Body; and a Description of the Human Pineal Organ Considered From the Clinical and Surgical Standpoints. By. R. J. Gladstone and C. P. G. Wakeley. Baltimore, 1940. Williams & Wilkins Co. Pp. 528, with 324 figures. $10.

This volume, written by a well-known London anatomist and embryologist and by a neurosurgeon, was prepared because its authors had found that the investigation of pineal tumors had proved rather fruitless, and they therefore "determined to investigate the whole question of the nature of the pineal organ from the lowest to the highest forms in the animal kingdom." Once embarked upon this stimulating project, they soon discovered that, in order to assess the true significance of facts which have been observed in connection with the mammalian epiphysis, it would be necessary to investigate the history of the pineal body and parietal sense organ from the standpoints of embryology, comparative anatomy, and paleontology. As Sir Arthur Keith points out in his introductory chapter, Gladstone, in tracing the origin and evolution of the human pineal, has gone back over a period of some four hundred million years, when median as well as lateral eyes had appeared on the head of our invertebrate ancestors. By comparing evidence from fossil remains and also from living creatures through the animal kingdom, a convincing story has been written of the way this structure attained the position of a visual organ with a lens, retina, and nervous stalk, and then, with the development of efficient lateral eyes, has retrogressed to its present unimportant position. The authors attempt to push back the origin of the pineal organ to the median eyes seen in many invertebrates. This possibility was first suggested by Gaskell, who did pioneer work on the pineal as well as on the autonomic nervous system. A double pineal stalk is present in certain forms of eels which is connected by nonmyelinated fibers with the habenular ganglia, and thence by the retroflex bundle of Meynert and stria medullaris with the olfactory apparatus. All these structures make up the epithalamus and may have formerly been concerned with feeding reflexes. Fusion of the paired earlier structures occurs in higher species of vertebrates, with retrogression of one side and its underlying nervous connections. In the cyclostomes (a primitive order of round-mouthed fishes, such as the lamprey eels and hag fish) the pineal eye may still act as a visual organ, although devoid of a lens. In the lizard the pineal organ lies just beneath the skin with central nervous connections which run through a foramen in the skull, but it is doubtful if this apparatus is sensitive to light. The same arrangement persists in tadpoles, but in adult frogs the nervous stalk is cut off by the cranial vault and only a spot of pigment is left beneath the skin. Only vestiges of the parietal sense organ and its stalk remain in the more primitive mammalian embryos and in the adult forms nothing but the basal segment of the pineal organ, the conarium, persists. The chapter on the pineal system of mammals omits interesting data on comparative anatomy, more especially the important contributions of Krabbe (1921, 1925, and 1929) and the studies of the pineal apparatus of marine mammals by Fuse (1936).

In the final third of the book physiologic evidence is reviewed, which shows that the mammalian pineal has not actually undergone metamorphosis into a gland of eternal secretion, but that the apparent endocrine changes produced by

certain pineal tumors, such as pubertas precox, in reality are due to compression of the hypothalamus. The surgical chapters include the pathology of pineal tumors, their symptomatology, clinical case histories, and operative technique. The chapter on symptomatology, especially the explanation of the characteristic limitation of eye movements, is particularly well done; but the chapter on case histories is brief and references to many cases of outstanding interest which have been reported in the literature are not included. As a result it is not possible to obtain an accurate impression of the life history of these tumors, or to define the operative risk involved in attempts at their extirpation, or to be certain about the amount of improvement that can be expected from radiation.

In evaluating the book, the comparative anatomical chapters, which make up its major portion, and its illustrations deserve the highest praise. From the more specialized viewpoint of the neurosurgeon, rather than from that of the comparative anatomist, this portion is too long and detailed, so that one cannot help feeling that condensation of the first 380 pages would clarify the evolutionary history. The glossary could well be enlarged, so that the surgeon who has not had an extensive zoological training could identify specias such as Petromyzon, Lacerta, etc. In the bibliography, since the method has been adopted of listing the articles by title, one wishes that this had been carried throughout consistently.

The Pathology of Internal Diseases. By William Boyd. Ed. 3. Cloth. Pp. 874, with 357 illustrations. Philadelphia, 1940, Lea and Febiger. $10.

This authoritative work, which first appeared in 1931, has been thoroughly revised and recent advances in internal medicine have been added. In the preface to the first edition the author stated that it was his purpose to correlate the symptomatology of disease with the pathologic lesions. He succeeded admirably in integrating pathology with internal medicine. The present edition includes new material on diseases of the heart, vitamin K, bronchogenic carcinoma, the relation of the pituitary to pancreatic diabetes, the anemias, renal diseases, and silicosis. While many sections have been rewritten and new material added, the number of pages remains approximately the same. Several new illustrations have been introduced, including four colored plates, all of which are appropriate to the text and are well reproduced.

Many factors have contributed to the success of this textbook. The author is a master of English prose. He constantly refers to and quotes passages from the medical literature pertaining to the subject under discussion. As an example, he presents Bright's own account of the clinical course of nephritis. In developing each section, a concise but lucid description of the normal histology and physiology is given, followed by a consideration of the morbid anatomy and its relation to symptoms. Well-selected references to the literature conclude each chapter.

A delightful feature of this book is the manner in which the pathogenesis of various diseases is presented. If controversial subject matter is discussed, the author cites the outstanding contributions on both sides and then develops his own opinion. In an inquiry into the pathogenesis of tuberculosis he terminates the discussion with the statement: "Immunity is the master word in tuberculosis. It is more to be desired than freedom from infection, for the latter is an unattainable ideal, and the rarer the infection, the more dangerous does it become." This assertion will be challenged by many. Again in a consideration of the pathogenesis of hyperthyroidism, he maintains that it is a mistake to separate

toxic adenoma from exophthalmic goiter: "Both should be included under the heading of Grave's disease. The adenoma is a mere incident in the course of the pathological process." The section on jaundice is excellent. Exception must be taken to one statement. In discussing the chromaffin cell tumor, also known as pheochromocytoma, he writes: "It is quite innocent, perfectly encapsulated, usually of small size, and may be found in elderly persons at autopsy by accident." It is now recognized that these benign-appearing tumors may secrete enough adrenalin to cause death.

This textbook is highly recommended to the medical student who has completed the introductory courses in internal medicine and pathology. It can be read with profit by every teacher and practitioner.

Die Entzündungsbestrahlung. By Dr. Med. Habil. R. Glauner. Paper. Pp. 190, with 14 illustrations and 14 tables. Leipzig, 1940, George Thieme. RM 15.

This monograph attempts to cover in a comprehensive manner the subject of inflammation treated by x-ray radiation. The book is divided into two parts. The histological, chemical, and physiological effects of x-ray radiation of inflamed tissues are considered in detail in the first portion. The second portion deals with the effects of roentgen therapy of inflammatory processes in various organs of the body. The world's medical literature on the subject has been painstakingly reviewed and admirably summarized. There is little that is original in the book, the author's contribution being chiefly his interpretation of the work of others and the recital of his results in the treatment of various inflammatory lesions with x-ray radiation. An extensive bibliography and a satisfactory index are appended.

The surgeon or general practitioner will hardly find it worth his while to purchase or read this book. It has a definite place, however, as a reference book and those in the profession particularly interested in roentgen therapy may find it valuable.

The Head and Neck in Roentgen Diagnosis. By Henry K. Pancoast, M.D., Late Professor of Radiology and Director of the Department of Radiology, University of Pennsylvania; Eugene P. Pendergrass, M.D., Professor of Radiology and Director of the Department of Radiology, University of Pennsylvania; and J. Parsons Schaeffer, M.D., Ph.D., Professor of Anatomy and Director of the Daniel Baugh Institute of Anatomy, Jefferson Medical College. Pp. 976, with 1,251 figures. Springfield, Ill., 1940, Charles C. Thomas, Publisher. $12.50.

In no region of the body is the anatomy more complex than in the head and neck. It is particularly fitting therefore that a dissertation on the roentgenology of this region should be based upon the concept of roentgen diagnosis as a visual presentation of gross anatomy, both normal and pathologic. This volume stands out as a splendid example of the results which may be achieved by a collaboration of the roentgenologist and the anatomist in the preparation of texts on roentgen diagnosis. The authors have covered the roentgen diagnosis of a series of diverse but grossly related structures in most admirable fashion. Practically all of the well-established data related to the roentgen examination of the skull and its contents, the various facial bones, the paranasal sinuses and mastoids with their associated structures, the jaws and the teeth, the cervical spine, the upper respiratory tract and the neck are in this detailed and well-ordered treatise.

For each structure there is a consideration of the normal gross anatomy and its variations, the normal roentgen anatomy, the technique of x-ray examination, and finally the roentgen diagnosis of disease processes. While the authors have drawn largely from their own rich experience, sufficient attention has been paid to the contribution of others. Each chapter contains a bibliography which, while not voluminous, is sufficient to give the references for almost all the subjects which are not fully covered in the book itself. The illustrations are unusually numerous, some 1,251 figures being exhibited. They are splendidly chosen, well arranged for accessibility and clearly labeled; many exceptionally fine anatomical figures are included. While the cuts are not as brilliant in detail as might be desired, with few exceptions they demonstrate all that is needed. The section on intracranial tumors and cerebral pneumography is especially well done. Some doubt may be held as to the lack of final proof of some of the cases presented, but in most instances there is no question as to the findings. The material in this book is much too extensive to permit detailed criticism; the reputation of the authors is sufficient to warrant the authenticity of the data. Considering the size of the book, the number of errors in the first printing is small. Attention should be directed to the transposition of Figs. 701 and 703 and to a few typographical errors in spelling. The publisher is to be commended for the format, the printing, the generous number of figures, and particularly for the reasonable price put upon so large and fine a volume. This is no doubt the most authoritative and most complete reference work we have on this subject; it will be indispensable to the roentgenologist, the neurosurgeon, the neurologist, the otolaryngologist, in fact to any physician concerned with the diagnosis of the diseases of the head and neck. It will remain permanently as a fitting memorial to the memory of the distinguished senior author.